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PLASTICS ENGINEERS JOURNAL

EPOXY CASTING RESINS FOR ELECTRICAL COMPONENTS

(Article on page 49)

MARCH, 1958 • VOLUME 14, NUMBER 3

A TECHNICAL REPORT FROM DU PONT

New process revolutionizes skin packaging

Du Pont ALATHON* polyethylene resin combines with Du Pont MYLAR** polyester film in a new skin packaging film which permits the use of uncoated, unperforated paperboards. Developed by the Print-A-Tube Co., Rochelle Park, N. J., the new film initiates mass usage and automation of the skin packaging process on commercial machinery.

The side of the new film coated with ALATHON 16 is heat-sealed directly to the paperboard, making coating of the board unnecessary. Since the board remains porous, the vacuum is drawn directly through the board, pulling the heated film tightly around the objects being packaged. Dwell time under the heater has been reduced to as little as two seconds and the time for pulling the vacuum to as little as three seconds. A single heat and vacuum cycle with the new film requires an average of ten seconds, compared with 40 seconds, *a saving in time of approximately 75%*.

Shelf life of the film is greatly improved. ALATHON 16 gives the film sealing qualities which are unimpaired with age and protects against moisture transmission. The film may be produced in thin gauges of .001" and .0025", because of its strength. In addition, the clarity of the film and its ability to reflect light are assets in improving package appearance.

Since coated paperboard is now unnecessary, there is no oxidation or discoloration of stored boards. Any number of boards can now be printed and held until ready for use. *Costs are greatly reduced* through the use of uncoated, unperforated boards and the elimination of inventory and waste problems.

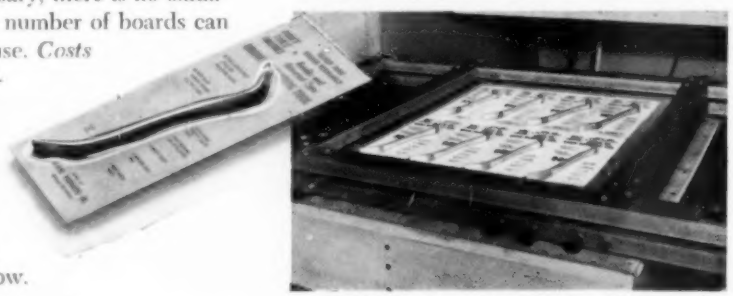
If you would like more information on this and other applications for the versatile family of ALATHON polyethylene resins, just fill in and send the coupon below.

*ALATHON is Du Pont's registered trademark for its polyethylene resins
**MYLAR is Du Pont's registered trademark for its polyester film

• Objects are positioned on paperboard at U. S. Packaging (contract packagers), Chicago, Ill.

• Skin packaging film, developed by Print-A-Tube Co., has been laid a few inches from board.

• Film is heated prior to vacuum process which draws film tightly over objects and against board.



• Finished card shows objects packaged in the tough, sparkling film for O.E.M. Products Co., Chicago, Ill.

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E. I. du Pont de Nemours & Co. (Inc.), Polychemicals Dept.,
Room 403, Du Pont Building, Wilmington 98, Delaware

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*Name*_____ *Position*_____

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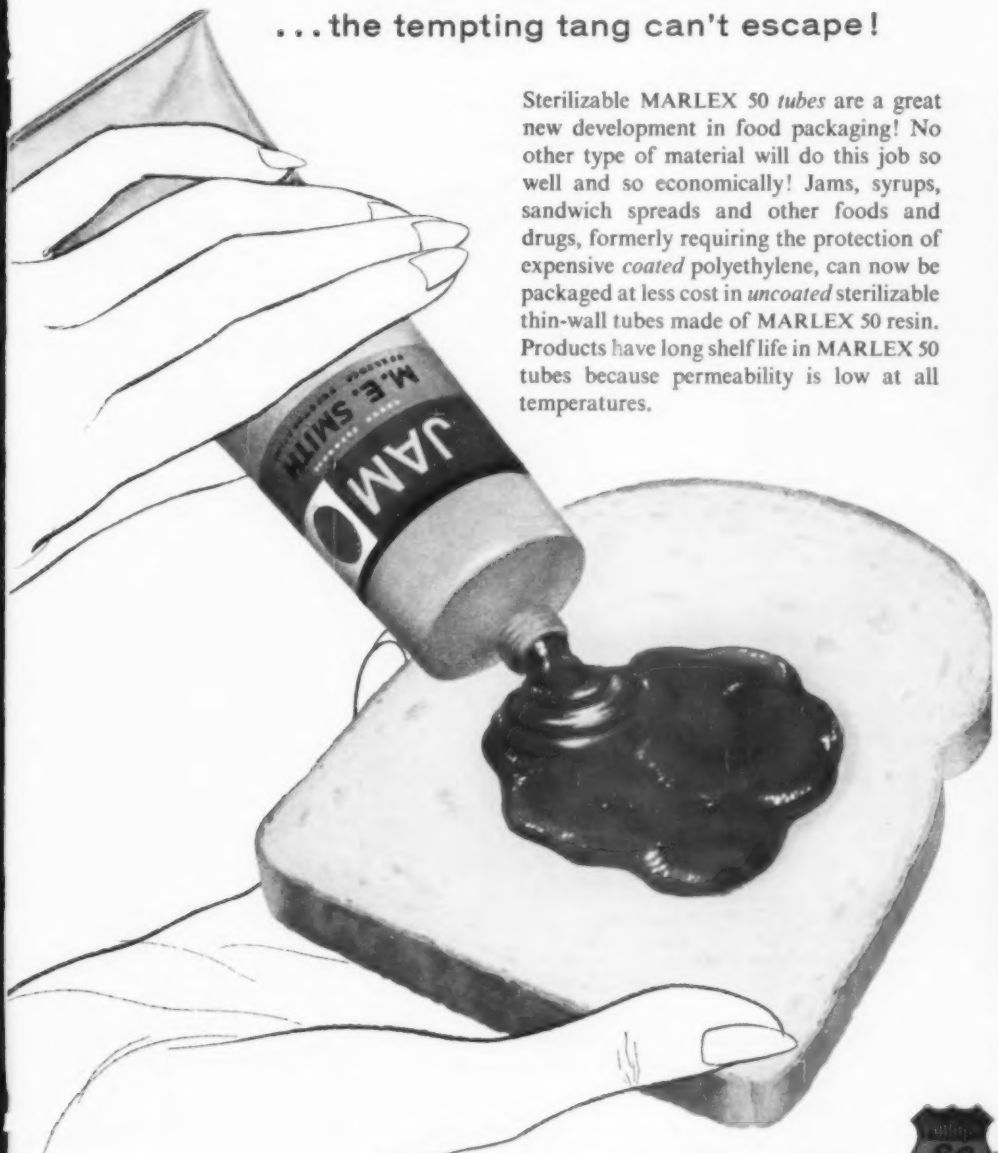

Sterilizable MARLEX 50 *tubes* are a great new development in food packaging! No other type of material will do this job so well and so economically! Jams, syrups, sandwich spreads and other foods and drugs, formerly requiring the protection of expensive *coated* polyethylene, can now be packaged at less cost in *uncoated* sterilizable thin-wall tubes made of MARLEX 50 resin. Products have long shelf life in MARLEX 50 tubes because permeability is low at all temperatures.

"Heat'n serve" frozen food packaging is one of the most promising applications for film extruded from MARLEX 50. Flavor is sealed in, and the housewife has no pans to wash!

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*MARLEX is a trademark for Phillips family of olefin polymers.

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And here it is at ERIE RESISTOR CORPORATION, Andover Industries Division, Andover, Ohio, molding Plexiglas instrument clusters for a 1958 automobile—in a two cavity mold.

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Daylight (Without Ejector Box)	58"
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Plasticizing Capacity (lbs. per hr.)	300
Horsepower	107½
Dry Cycles (per hour)	300

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SPE JOURNAL

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15th ANTEC—New York 1959

This is our first call for papers for the 15th Annual Technical Conference, sponsored jointly by the Newark and New York Sections to be held in New York at the Hotel Commodore, January 27-30, 1959. We need your help in assembling a high-quality technical program yielding new information of interest and utility to the Plastics Engineer.

As you well know, the Society of Plastics Engineers is the leading professional society dedicated to the promotion of ". . . the Arts, Sciences and Engineering Practices and Standards connected with the utilization of plastics." Only by the presentation of a well-rounded program demonstrating new developments and advances made in the past year and by giving a picture of what the future holds in store—can the objectives of SPE and its members be attained.

Your 1959 ANTEC Co-Chairmen, Guy A. Martinelli (New York Section) and James T. Growley (Newark Section), their Executive Committee and Committee Chairmen, are already hard at work developing a Conference of lasting interest and value to all SPE members. Your participation and cooperation will insure the success of the 15th Annual Technical Conference in New York.

Notices will be in the mail shortly to all SPE members requesting papers and suggestion for this meeting. Please reply to Dr. Alex Sacher, Program Chairman 15th ANTECS—New York 1959, c/o Standard Insulation Company, 74 Paterson Avenue, Rutherford, New Jersey.

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Where do you fit into this

Products of PLASKON Plastics and Resins in this kitchen:

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Polyester Resins—translucent panels, chair

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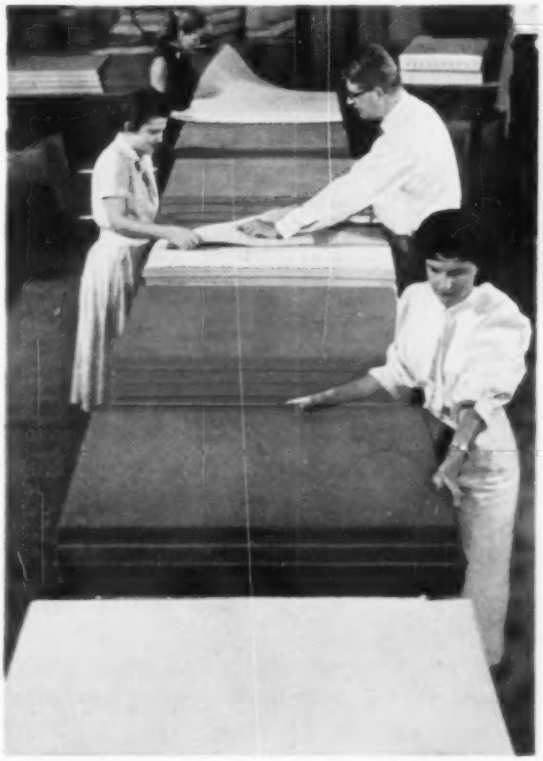

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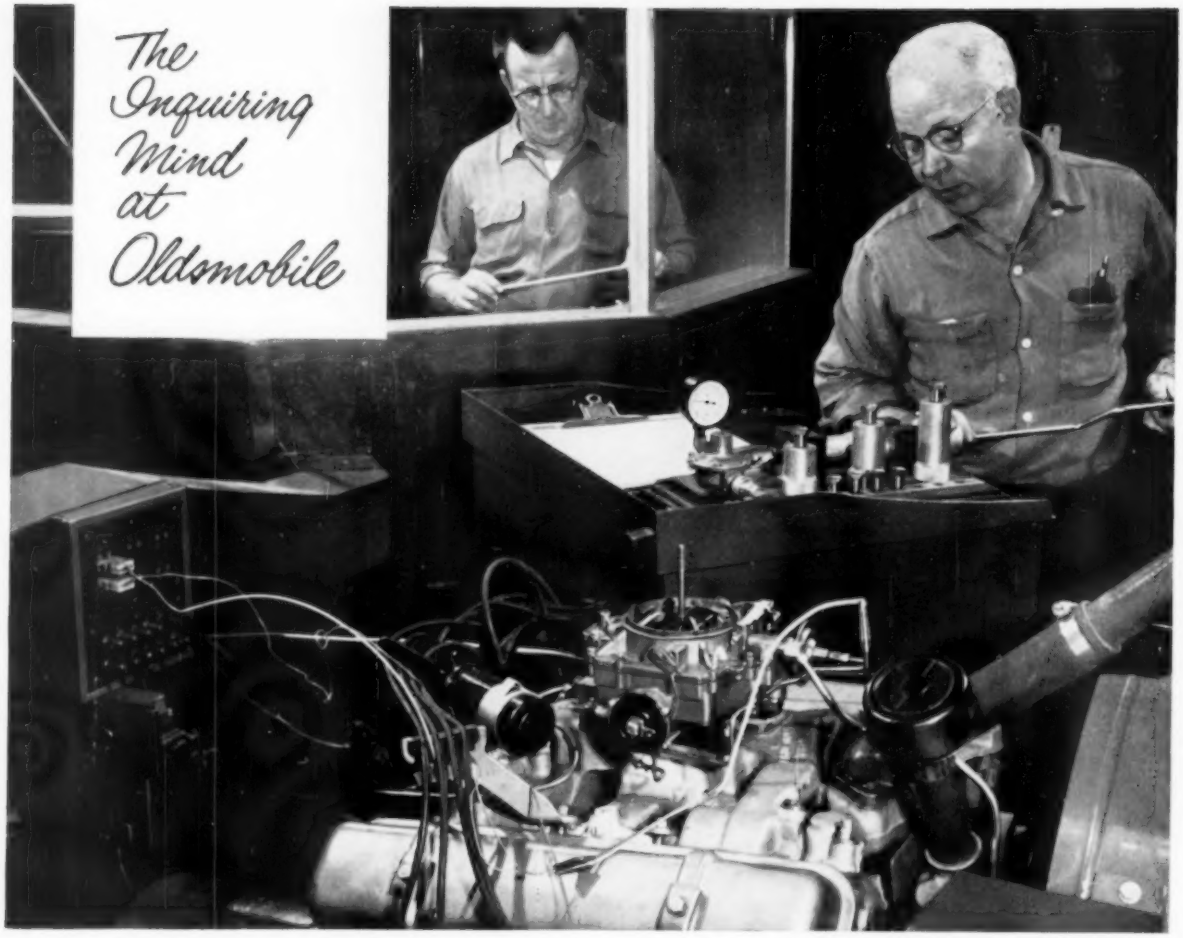

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From the Editor's Notebook

By Jesse H. Day

● This issue completes a job that was begun in 1945, when your editor first took over the 4-page SPE News Bulletin. Now, thirteen years later the Journal has grown to such an extent that the part-time efforts of a single person is not enough. To make future growth possible, Charles Rhine will become successor and full-time editor.

As soon-to-be Editor Emeritus, your editor extends his heartfelt gratitude to the many men who gave, and are giving, unselfishly and importantly of their time and energies for the SPE Journal—and through the Journal to the whole industry. The list is long—over 100 men at the present—who serve as abstractors of foreign magazines, book reviewers, section news reporters, feature editors, members of the editorial advisory board and the publications committee. It is these men who have made the SPE Journal and the SPE the useful organizations that they are. A humble bow and sincere thanks to them all!

Your editor looks both forward and backward with pleasure—back over the years with the Journal, and forward to a continued but much reduced function with the Journal, and a great deal more time to spend on research in that unusual class of compounds, the fulvenes.

● A new journal which may be of interest to rheologists is "The Physics of Fluids", the first issue being Jan.-Feb. 1958. Publisher is the American Institute of Physics, 335 East 45th St., New York 17, New York.

● One of the finest plastics magazines is Kunststoffe. Since most companies spend a good deal of time and money translating the articles from German to English each month, the publishers of Kunststoffe are pondering the possibility of including substantial English translations. They will, if enough subscribers are obtained to cover costs, starting with the July 1958 issue. Price will be $32 a year. If interested, write to Erich Escales, Kunststoffe, Wiesbaden, Biebrecher Allee 57, Germany.

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Plastics in the Automotive Industry

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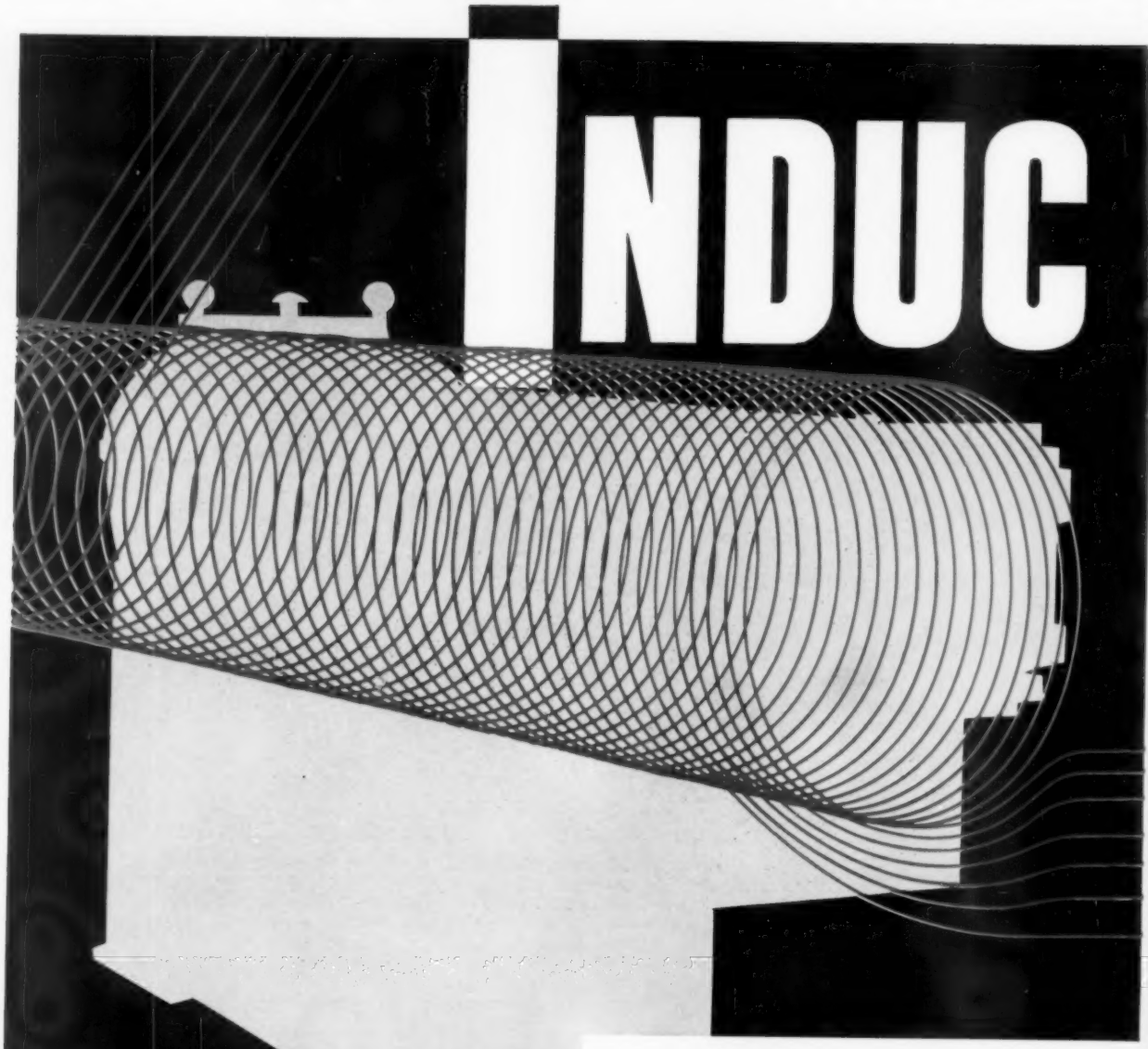

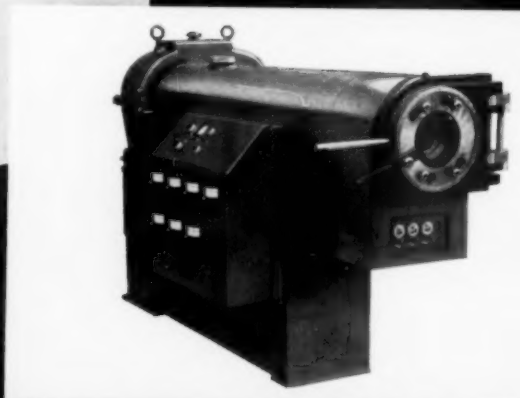

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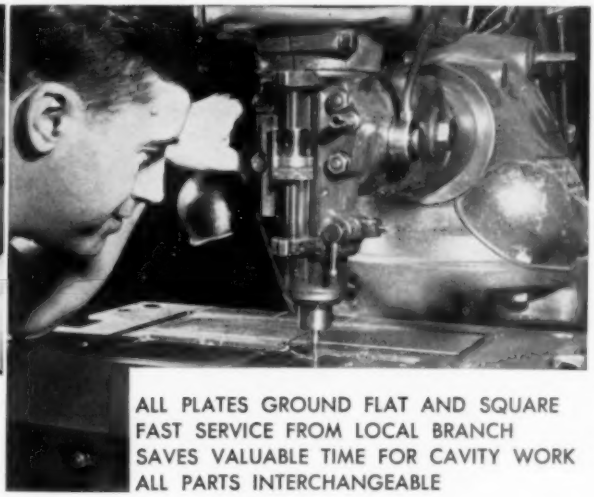

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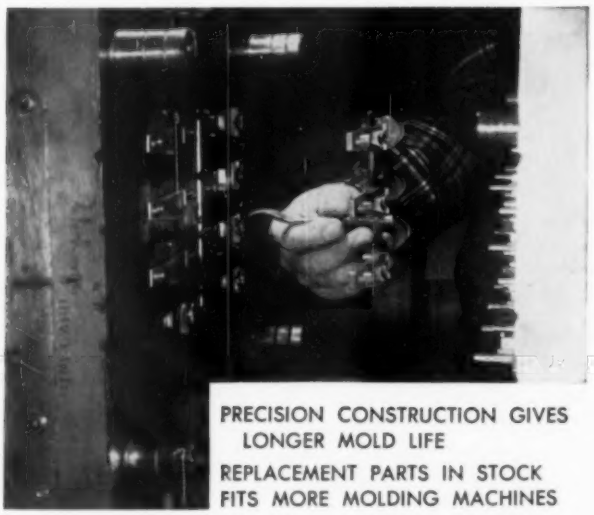

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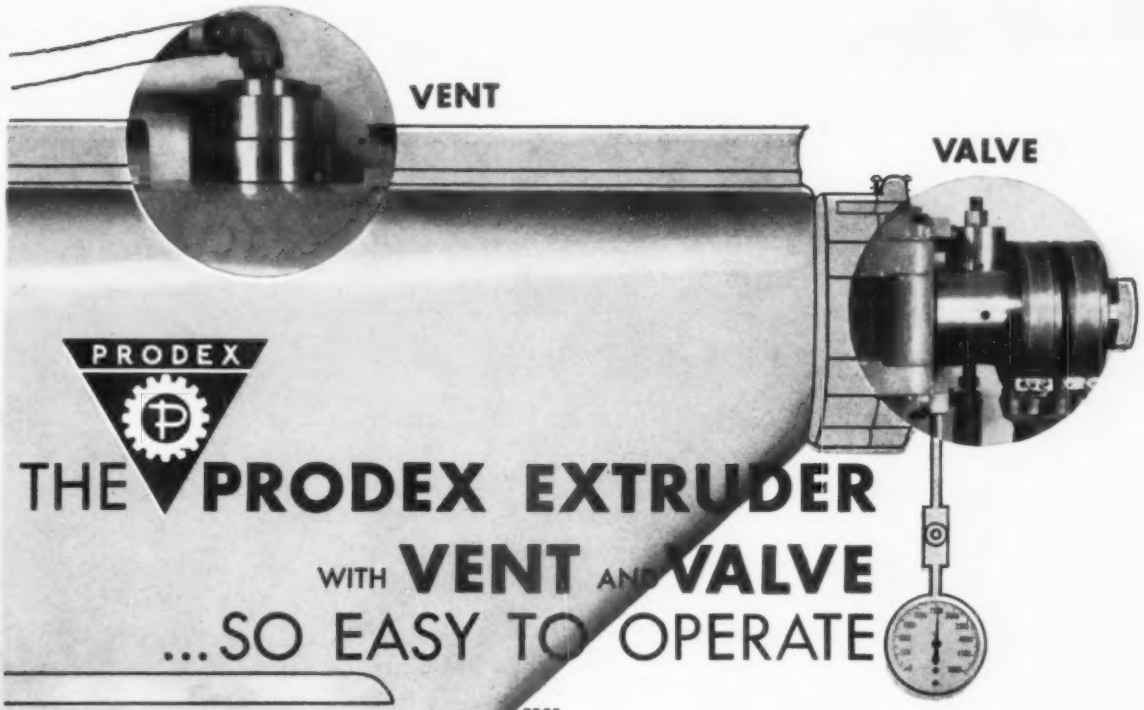

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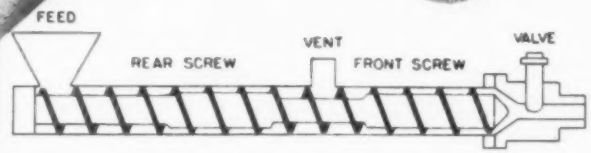

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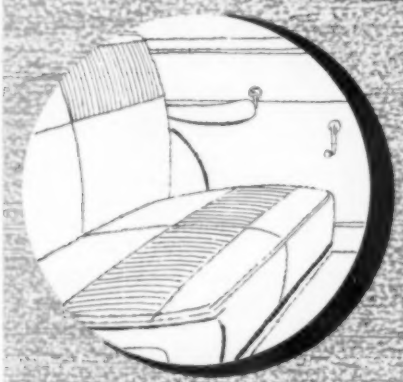

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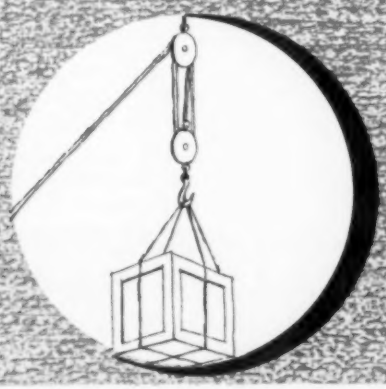

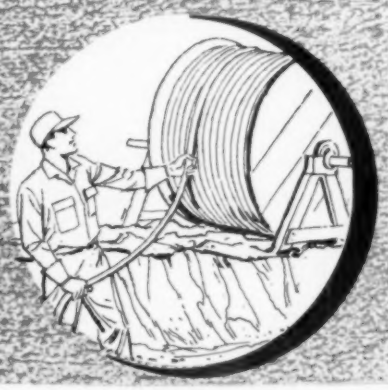

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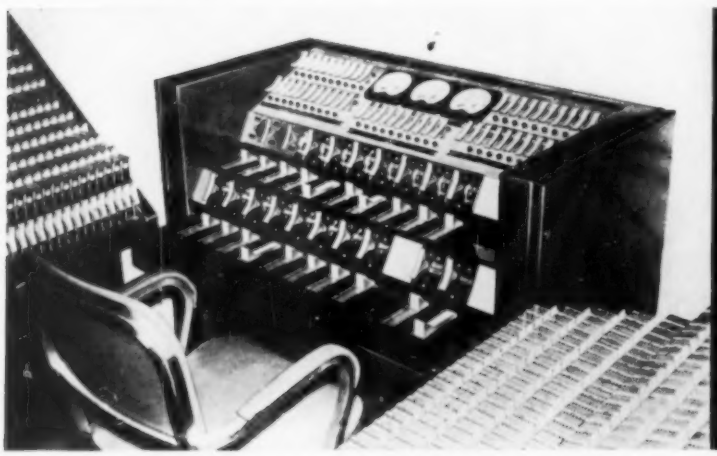

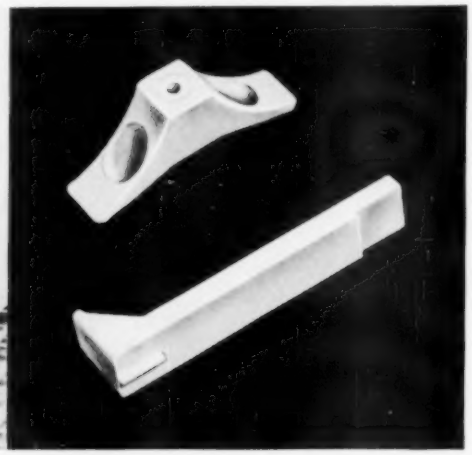

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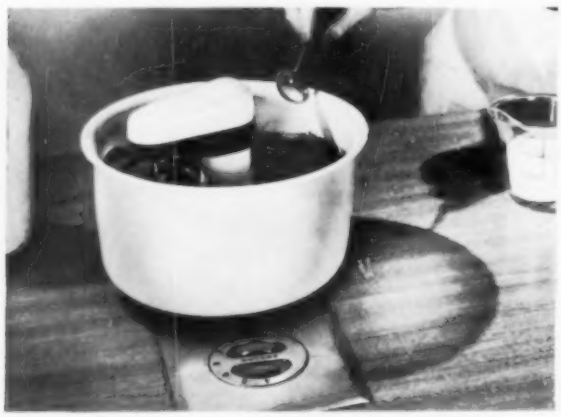
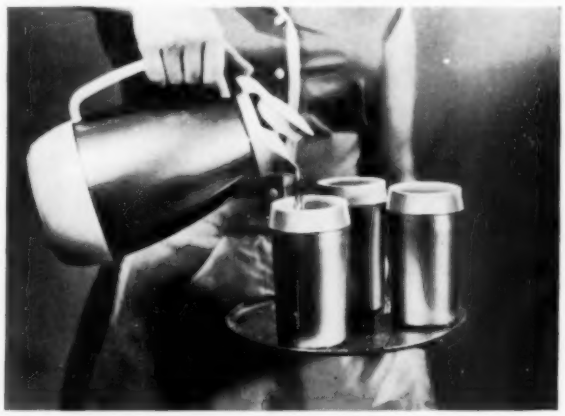


"Five-in-One" Counter-Top Appliance Features CYMEL® Plastic Accessories

The new multipurpose NuTone Food Center operates a mixer, blender, meat grinder, knife sharpener and fruit juicer from one motor that can be set flush in a counter top Counter clutter, tangles of electric cords and heavy separate appliances are eliminated. A gleaming white 3½-quart bowl made of CYMEL melamine molding compound serves the mixer and juicer. CYMEL makes the bowl lightweight, dent-proof and easy to handle. The bowl is molded for NuTone, Inc., by Prolon Plastics Division of Prophylactic Brush Co.



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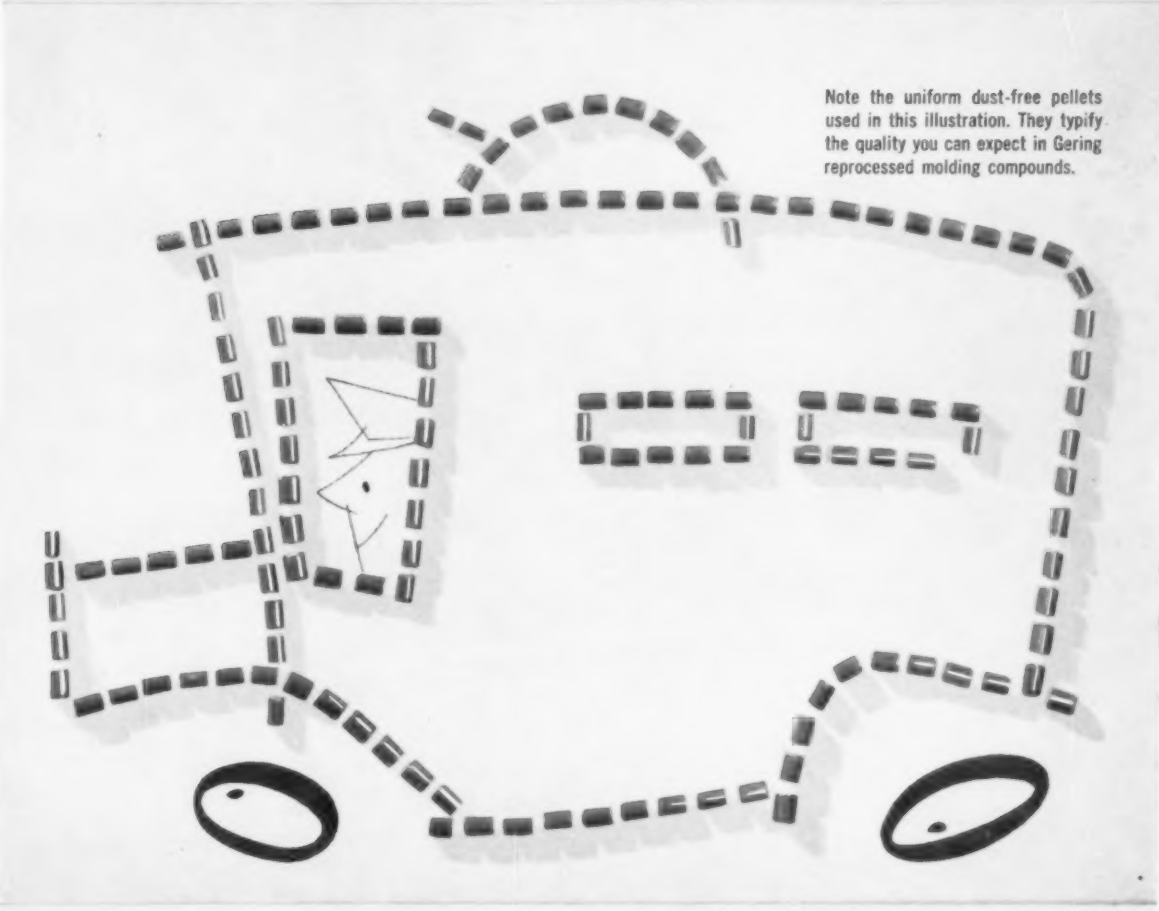

Note the uniform dust-free pellets used in this illustration. They typify the quality you can expect in Gering reprocessed molding compounds.

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PLASTICS ENGINEERS JOURNAL

Volume 14, Number 3 • March, 1958

The Future of Plastics In the Automotive Industry

Charles A. Chayne

Vice President in Charge of Engineering Staff

General Motors Corporation

I would like to suggest a few applications that could be most helpful to the industry to encourage some thought and offer you challenge. There is so much yet to be done in the area of adhesives. It would be so helpful if metal trim parts could be cemented to the car to replace the wide variety of fastening clips and accurate hole cutting in body panels. Body solders are expensive. Smear-on plastic materials equally as good, less expensive, and lighter in weight are yet to be developed. Protective coatings for exterior bright parts subject to the corrosive conditions of street salt, etc. that are non-dulling, long-lasting and hard surfaced could have important application. The large and compounded curved glass windows in today's automobile present serious handling problems in production and costly replacement in the field. Rubber oil seals present some problem today as a result of the oil industry's constant improvement in oil by the addition of new additives. Plastic fuel lines would have great value in the industry.

New Qualities Sought

We have yet to control metallic flake in producing plastic parts with metallic appearance.

An ultimate to look forward to would be to combine the strength of thermosetting plastics with the process ability of thermo-plastic.

Upholstery fabricates may some day completely eliminate the need of seat covers. Plastic upholstery fabrics whose edges can be easily heat sealed effectively and economically have a place in the future of the automobile. Thermo-setting plastic laminates and printed circuitry offer so much promise. In general terms, the car manufacturers are seeking plastics with higher strength, better cold-flow properties and lower cost. Speaking of my own organization, the GM engineering departments are constantly trying to save money but not at the expense of quality. In many cases, money is spent to eliminate nuisances and to give our customers more quality even in small and relatively unimportant places. The use of nylon for our dome lamp lenses is a good example. Here is a case where less expensive plastics are known to darken with age from the heat of the lamp.

Many excellent plastics fail in one very important property—they change with age and exposure to sun and other climatic conditions.

Big Future

Yes, I think we would all agree that there is a big future for plastics in the form of products for the automobile industry. Future expansion of the use of plastics in automotive applications will depend not only on the new materials yet to be developed, but also on the intelligent use of the materials available today. The plastic industry can assist best by continuing the development of its relationship with the automotive industry so that all the facts about its products can be properly evaluated and in the most intelligent manner possible.

So far remarks have primarily centered on product. There is another area in the automotive industry where plastics are beginning to play a very important role. The relatively new application of plastics as tooling material has found widespread and successful application within General Motors. This field has and will continue to contribute substantially to an overall reduction in the cost of tooling.

The value of the use of plastics for tooling is evidenced by faster tool fabrication, lower tool costs, lighter weight tools, and easier modification of tools which become involved in engineering changes.

Complete tooling programs in plastic can be completed in one-third to one-half the time required to produce an

Excerpts from the talk presented before a luncheon meeting of the SPE at the 14th Antec.

identical program of conventional tooling. Many forming dies can be made with plastic in a matter of days, in contrast to weeks and months required to produce their conventional counterparts. Of importance, too, is the fact that spotting is eliminated when dies are made from plastic. No machining is required on a plastic die and intricate contours which heretofore required extensive machining are duplicated with ease.

Cost Savings

As previously stated, reduced fabrication time is only one of the major advantages plastics, as tooling material, have in their favor. Cost savings resulting from the simplification of production operations and lower initial investment are of equal importance.

Plastic tools, as such, retain the inherently advantageous characteristics of the materials of which they are made. They are light in weight, dimensionally stable, accurate and durable. In every respect, a model or Keller master made from plastic is much better than the original wood or plaster type.

Additional advantages of prime importance with respect to plastic tooling are reflected in initial tool and die tryout and the ease with which modifications demanded of design changes are made. A plastic tool can be put into production well ahead of a permanent steel tool. This, of course, facilitates early production of parts and adequate time to check for design errors. Spring back in metal and blank size can be readily determined. And of tremendous importance, too, is the fact that experimental and prototype parts can be economically developed.

Rubber and Plastics Committee

Plastics have been given a definite degree of importance in the General Motors organization. In fact, if you will recall, a General Motors Research Staff man was your society's first president, Bill Phillips. We have a rubber and plastics committee which meets regularly and affords an opportunity for people within General Motors to exchange information and experience on the varied applications of plastics among our several divisions. This committee now confers with your research people to create a better understanding of each other's products.

In this area it also serves as an excellent medium for the presentation and introduction of new plastic materials and products by your industry to our organization.

Our production standards books keep up to date the latest specifications, design data, and recommended applications for the many plastics both from a product and tooling standpoint. These books are, of course, used by all of our divisions.

Our Research Staff has for years analyzed each new development of your industry for all of our divisions as to possible applications to our own products. Naturally we believe everything your sales people tell us—particularly after we have thoroughly checked it ourselves. Our Research Staff is also creating new plastic materials specifically adapted to our own products wherever the need is felt and is not being satisfied by your industry.

Our Process Development Staff has recently set up a shop dealing with the application of plastics from a tooling standpoint. This activity does development work on formulations and procedures and assists the various divisions of the Corporation with their plastic tooling problems. Currently the important phases of plastic tooling under study by this activity are: (1) Materials that will resist distortion at temperatures in excess of 500°F., (2) pressure fabrication techniques necessary to produce tools of superior quality, (3) metal faced plastic tools for increased productive life, (4) compounding epoxy resin alloys with other resins and plastics to improve properties, and (5) high strength and low cost plastic materials for casting dies. Cost of the latter is expected to be less than ten cents a pound.

Some of the areas in which GM Divisions have successfully adapted tools made of plastics are: Plastic forming and drawing dies to fabricate stainless steel up to .080, all plastic hydroform punches which operate at 13,000 psi, drill fixtures and templates, models and Keller blocks, and machine, checking, and assembly fixtures.

Recently our Fisher Body Division completed in less than a week a draw die in plastic for forming a body underpan for a prototype model where previously several weeks' work would be involved at considerably greater expense.

The use of plastics as tooling material is an established reality. The constant search for new materials and new applications is destined to become an entirely new era with respect to production tooling.

Use Will Increase

General Motors believes that the use and value of plastic tooling will increase with developments which will contribute to faster fabrication, lower cost, reduced weight, and increased ease of modification. In addition, improved materials and methods are certain to add to their popularity.

The future of plastic tooling is bright. The continued advancement in this fascinating field offers a challenge to development-conscious plastic engineers and the inquisitive minds of tool engineers.

I have already suggested applications from a product standpoint that your industry might consider. Several restrictions presently retard the use of plastic tooling as a substitute for conventional tooling. Its value in tooling will be unlimited if its use can be improved and expanded to include long production runs.

Materials consisting of better wear characteristics and better resistance to heat must either be found or developed. Better fabrication techniques which will enhance physical strength will have to be developed.

Finally, the cost of new materials must be reduced. Is it not possible to consider for the future a low cost, high strength, heat resistant plastic which could be poured into a mold to produce a die whose qualities would approach those of a steel die? Such a material would be of immense value to the automobile industry.

Injection Mold Dies

A low cost material impervious to heat but a good heat conductor that could be cast to make injection mold dies for producing parts would also be of immense value.

Your industry faces a great challenge to expand the widely accepted plastic tooling so advantageous to short runs, into an even more fruitful facility for high production.

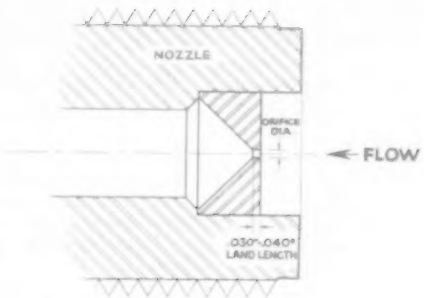
Is there reason to question the future of plastics in the automotive industry? Based on your past and present performance, there certainly is not. Plastics have a future in every phase of all industries.

The automotive industry, as you well know, is a highly competitive industry geared to produce in quantity a product continuously improved in appearance, safety, feature and performance whereby each new model will create a desire in its customers to replace their present models.

All industry has common objectives with relation to the future. All industry is faced with the challenge to insure continued economic progress of our country and to safeguard its very existence. ★★

A New Breaker Plate for

Coloring Polyethylene



The Venturi Breaker Plate

J. E. Simpson

Ferro Corp., Color Division

Cleveland, Ohio

The term "dry coloring" commonly describes the process of in-plant coloring used by injection molders. Pigments, or colorants, in the dry powdered state, are blended with resins.

This blend is transferred to the hopper of the injection molding machine and processed in the same manner as precolored material. The molder's aim is to produce a colored part of the highest quality.

Prior to the appearance of high-melt index, low-density polyethylene and high-density polyethylene, injection molders had little dry-coloring difficulty. But as these new resins appeared in the field, it became immediately apparent that they could not be satisfactorily colored unless the polyethylene pigments or dispersing methods then in use were improved.

Certain improvements have been made in pigment formulations but this has not been the whole answer. As a further aid, resin suppliers have conducted extensive laboratory and field experiments. Their findings introduced systems of dispersion aids and molding techniques which improved the dispersion of pigments in their individual polyethylene resins.

Some molding shops, working closely with color and resin suppliers, have been able to solve dispersion problems. However, the results have not been uniform throughout the field. The need still exists for a simple dispersion technique that may be employed inexpensively by all molders.

This paper is a revised and extended version of the paper presented at the Fourteenth SPE Technical Conference.

Conventional Dispersion Aids

The term conventional is perhaps a misnomer. Actually there is no conventional dispersion aid for all polyethylene resins.

Some of the types in use are:

(1) Circular Disk with Straight-Through Holes: The number, diameter, land length and position of these holes all appear to be critical factors in the success of this disk.

(2) Circular Disk with Small Holes Leading to Larger Holes: The same variables exist here as with Type (1).

(3) Pineapple Nozzle Insert

(4) Ball Bearings Inserted in Nozzle

(5) Screen Packs

There are other techniques and variations of each. The relatively long list of dispersion methods stems from the fact that no one type has yet proved capable of working in all of the different polyethylene resins now in use.

Types (1) and (2) mentioned above have, in our experence, met with more success than have the others. Mixing is induced because the molten mix is forced through restricted channels of varying land lengths and diameters.

Purpose

The prime objective of this study was to develop a technique which would enable any injection molder to dry color any polyethylene resin with good results.

Early in the program it became apparent that quality of dispersion could be improved through the proper selection of the pigment and pigment concentration.

A new type of breaker plate, referred to as the "Venturi Plate", has been developed and has undergone laboratory and field evaluation. (See Title Figure)

With the development and perfection of the Venturi Plate an attempt is being made to:

(1) Develop a dispersion aid simple in design.
(2) Determine, through experimentation, the optimum values for the variables involved so that the molders might use the plate with a minimum of "trial and error".
(3) Develop a dispersion aid that will color with a minimum pressure loss. This is of principal importance where machines are operating at capacity.
(4) Publicize this development and make either the plans of the Venturi Plate or the plates themselves available to all molders.

Simplicity of Venturi Plate Design

The Venturi Plate is basically an advanced simplified version of the common breaker plates now in use. It carries a single orifice of very short land length.

Determining the Critical Variables

To determine the most efficient dimensions, the practicality of the Venturi Plate for production coloring, and the quality of coloring, two distinct test programs have been conducted.

Field tests were run to evaluate the new breaker plate in terms of production coloring and better dispersion.

Laboratory tests were run to get more data on these two aspects, but chiefly to determine if molding pressure loss would be too extreme.

Field Tests:

The first field tests were made in a six-ounce machine molding a one-ounce part. The part was a tumbler. The mold was center gated. Many representative grades of polyethylene resins were used;

(1) low-density, low-melt index.
(2) low-density, high-melt index.
(3) intermediate density.
(4) high-density, low-melt index.
(5) high-density, high-melt index.

All of these materials were dry colored with ease when using the Venturi Plate. The machine was not perating at its capacity and therefore, accurate pressure-loss data could not be obtained. It was not necessary to make any radical cycle changes during this test. The only changes were those needed to run the different density and melt index materials.

This first test proved that the Venturi Plate made dry coloring easy regardless of material used . . . but did not prove that it was usable for larger parts. Nor did this test provide any data on molding pressure loss, of prime importance, in a great many cases.

The second field evaluation was conducted molding a small waste basket (130 grams) with a 24 melt-index material. The molder was obtaining good dispersion using a system of his own development and through the use of good polyethylene pigments. Here it was decided that in addition to studying Venturi Plate performance, an attempt would be made to determine how dispersion was affected by adding small percentages of low-molecular-weight polyethylene.

Venturi Plates with three different hole sizes were compared to the dispersion plate being used by the molder. All Venturi Plates had a short land length, 0.040 inch.

Mixtures containing 0%, 2%, and 4% of low-molecular-weight polyethylene were used. The results are tabulated in Table I.

Again, in this second field trial, the machine was not operating at its capacity, however, very interesting data was derived.

It was also interesting to note that by merely increasing the amount of low-molecular-weight polyethylene from 2 to 4%, the quality of dispersion was increased from fair to excellent when using the molder's breaker plate.

The third field trial was conducted using high-pressure high-melt index polyethylene.

The molder was obtaining fair to good dispersion using a breaker plate developed jointly with his resin supplier.

A Venturi Plate with an orifice diameter of 0.052 inch was tried and dispersion results were comparable to the production runs. The orifice diameter was reduced to 0.050 inch. Dispersion results were immediately improved. It was necessary, however, to increase molding pressure slightly.

It was felt that a slightly larger hole . . . perhaps 0.043 inch in diameter . . . would lower the pressure loss without affecting the very good dispersion results. The molder, however, continued to use the Venturi Plate with the 0.040 inch orifice.

The field tests indicated that the Venturi Plate was practical for production dry coloring. It was necessary to determine if the molding pressure lost by using a Venturi Plate with a small orifice diameter was excessive or not. A series of laboratory tests were conducted to evaluate this and also color dispersion.

Laboratory Tests:

The first evaluation involved low-density high-melt index polyethylene. Six Venturi Plates were evaluated. Four were in a series having a constant orifice diameter, but varying in land lengths. The remaining two were random checks. The purpose of this series of tests was to relate color dispersion and molding pressure loss to land length and orifice diameter. Pigment concentration was also studied.

Table I
Second Field Evaluation
24 Melt Index, High Pressure Polyethylene

DISPERSION PLATE	100% POLYETHYLENE	98% POLYETHYLENE 2% LMW* POLYETHYLENE	96% POLYETHYLENE 4% LMW* POLYETHYLENE
PRODUCTION BREAKER PLATE	×	FAIR DISPERSION	EXCELLENT DISPERSION
VENTURI PLATE .043 ORIFICE	POOR FILL, TOO MUCH RESTRICTION	×	×
VENTURI PLATE .052 ORIFICE	VERY GOOD DISPERSION	EXCELLENT DISPERSION	×
VENTURI PLATE .063 ORIFICE	GOOD FILL, POOR DISPERSION	×	×

· LEGEND ·
* LOW MOLECULAR WEIGHT
× NOT CHECKED

A six-ounce injection molding machine was used. A quart container mold was used to measure injection pressures. A 3/16" spiral mold was used to determine the molding index (see Modern Plastics, "Spiral Flow Molding," L. Griffith, August, 1957).

The material used was low-density (.926) polyethylene with a melt index of approximately 20. Two pigment blends were used . . . Turquoise and yellow at two concentrations. The majority of evaluations were made with the yellow pigment at a 0.5% concentration.

The molding index test with the spiral mold was performed at temperatures of 350°F and 450°F. The number of inches of flow along the spiral mold was determined. The only variable vas the Venturi Plate land length. The orifice diameter was constant. The standard reference was molded with no Venturi Plate. The tabulation and graph of results is shown in Figure 1. The graph of results shows clearly that as the land length of the orifice is decreased . . . keeping the orifice diameter constant . . . the molding index approaches that of the no-plate condition. The slopes of the curves are the same for both temperature runs.

The minimum molding pressure necessary to obtain a satisfactory quart container without a Venturi Plate in the nozzle was used as the standard reference for determining injection pressure loss. The molding pressure necessary to get a properly filled mold using different Venturi Plates in the nozzle was determined. These pressures compared to the standard, no-plate pressure are shown in Figure 2.

The curves of the results, Figure 2, illustrate graphically the degree to which molding pressures decrease as land length of the Venturi Plate is decreased keeping orifice diameter constant. (Curve I, Figure 2)

Curve II illustrates the degree to which molding pressures can be decreased by increasing orifice diameters from merely 0.030 inch to 0.050 inch.

Various random checks with Venturi Plates were made in which yellow pigments were increased from 0.5% to 1.0% and turquoise pigments at 0.5% and 1.0% concentrations. The results of this test indicated that orifice size is the prime factor in color dispersion. Quantity and type of pigment also affected dispersion. Increasing land length merely increased the pressure loss and did not affect dispersion.

Figure 3 is a picture of three representative quart containers molded for this test. This picture illustrates the degree that color dispersion was improved by using the Venturi Plate with .030 inch diameter orifice and .040 inch land (compare containers 1 and 2). A comparison of containers 2 and 3 illustrates the small degree of dispersing efficiency lost by increasing the orifice diameter from .030 inch to .050 inch. This increase in diameter of only .020 inch enabled the molding pressure to be lowered substantially, however.

Additional dispersion tests were made on linear polyethylene. Nine Venturi Plates of varying land lengths and diameters were evaluated.

An eight-ounce injection molding machine was used. The mold was a 3" x 4" x 2" box. The material was linear polyethylene with a melt index of 5 and density of 0.955. Pigmentation was .5% of the same type of yellow used in the previous experiment. Again dispersion and molding ease with Venturi Plates installed were compared to results obtained with no plate installed.

Figure 1. Molding Index (Spiral Mold). (orifice diameter 0.030)

		NO PLATE	Plate 1	Plate 2	Plate 3	Plate 4
CYLINDER TEMP.	350°	29.3"	24.6"	25.2"	26.6"	27.2"
	450°	41.6"	37.1"	37.9"	39.0"	39.8"

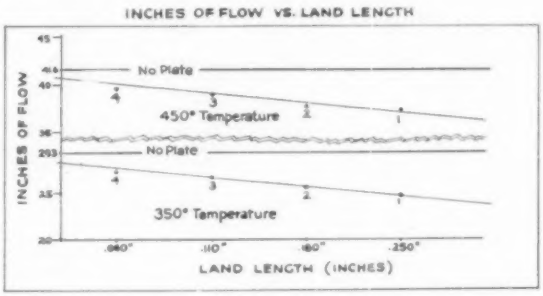


Figure 2. Molding Pressure for the Quart Mold.

	NO PLATE	PLATE 1	PLATE 2	PLATE 3	PLATE 4	PLATE 5	PLATE 6
ORIFICE DIAM.	—	.030"	.030"	.030"	.030"	.050"	.050"
LAND LENGTH	—	.250	.180"	.110"	.040"	.040"	.500"
MOLDING PRESSURE (PSI)	12,500	17,000	16,000	15,000	14,500	13,000	14,000

Molding Pressure vs. Land Length

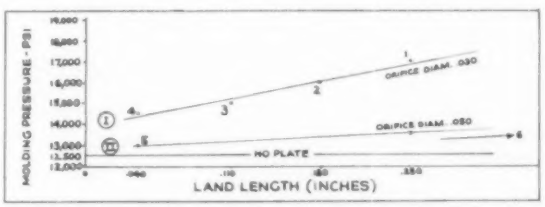
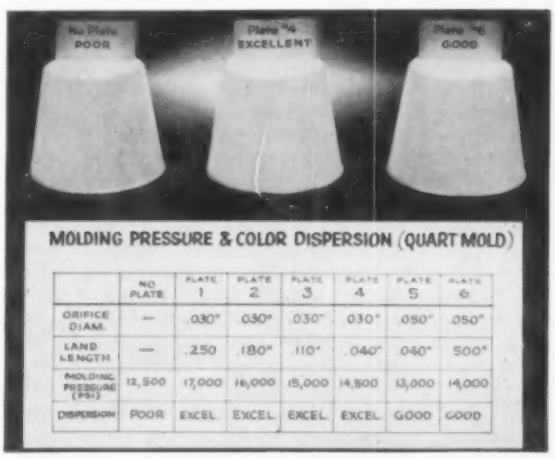


Figure 3.



	NO PLATE	PLATE 1	PLATE 2	PLATE 3	PLATE 4	PLATE 5	PLATE 6
ORIFICE DIAM.	—	.030"	.030"	.030"	.030"	.050"	.050"
LAND LENGTH	—	.250	.180"	.110"	.040"	.040"	500"
MOLDING PRESSURE (PSI)	12,500	17,000	16,000	15,000	14,500	13,000	14,000
DISPERSION	POOR	EXCEL.	EXCEL.	EXCEL.	EXCEL.	GOOD	GOOD

Figure 4. Dispersion Evaluation of Venturi Plates for Linear Polyethylene.

VENTURI PLATE	ORIFICE DIAM.	LAND LENGTH	MIN. MOLDING TEMP. (100% FILL)	QUALITY OF DISPERSION
NO PLATE	——	——	330°	POOR
1	.040"	.037"	390°	EXCELLENT
2	.040"	.174"	410°	GOOD
3	.040"	.255"	420°	GOOD
4	.060"	.040"	340°	GOOD
5	.060"	.105"	370°	GOOD
6	.060"	.177"	360°	GOOD
7	.073"	.255"	365°	GOOD-FAIR
8	.080"	.040"	350°	FAIR-POOR
9	.101"	.040"	340°	POOR

Because only minimum injection pressure was required to fill the mold, it was necessary to use minimum molding temperature as the control variable. It was found that the molding temperature was critical.

The minimum molding temperature for 100% mold fill was recorded for each of the Venturi Plates and for the no-plate run. A comparison of these temperatures gives a relative comparison of the resistance to flow, set up by the Venturi Plates. The results are presented in Figure 4. A visual comparison of all pieces made using a Venturi Plate, shows very little difference in the quality of coloring. Figure 5 is a comparison of two containers molded with Venturi Plates and one molded with no Venturi Plate. As can be seen there is very little difference between the dispersion quality obtained by using a .040 inch orifice and that obtained by increasing the orifice diameter to .080 inch.

Varying the land lengths, while keeping the diameters constant, did not appear to have any effect on quality of color dispersion. But in each case of longer land length with the same diameter, higher molding temperatures were required and flow resistance increased.

The smaller diameters did slightly increase the color dispersion of the linear polyethylene and color mix.

Conclusions

From these tests, the following conclusions can be drawn:

Orifice Diameters

The size of the orifice is critical with all polyethylenes. It is very critical with high-melt index polyethylene, however the diameter does not seem to be as critical with low-melt index and linear polyethylene.

With high pressure, high melt-index polyethylene increasing the diameter slightly decreases the quality of dispersion... from excellent to good. With the linear polyethylenes, changing diameters below 0.070 inch appears to have little effect on dispersion.

Decreasing diameters produces better color dispersion, but necessitates the use of higher molding pressures or temperatures or both. Optimum orifice diameters can be determined from all melt index, shot size, resin density conditions. A chart of suggested orifice diameters has been compiled for all conditions. A range of orifice diameters is suggested for each condition. This chart is presented in Figure 6.

Figure 5. Comparison of Container Molded with Different Plates.

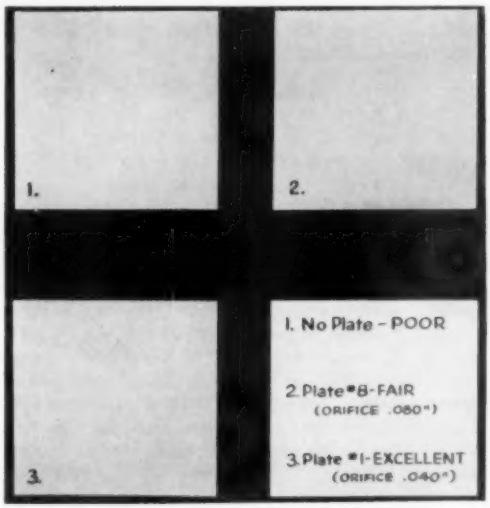


Figure 6. Venturi Plate Orifice Charts.

DENSITY	MELT INDEX	SHOT SIZE IN OUNCES 1-4	4-8	8-12	12-16	16-20	20-24	24-28	28-32
.914 TO .927	3.5 TO 10	.045" TO .065"	.045" TO .062"	.050" TO .070"	.060" TO .080"	.070" TO .090"	.080" TO .100"	.090" TO .110"	.100" TO .120"
	10 TO 24	.025" TO .050"	.030" TO .060"	.040" TO .070"	.050" TO .080"	.050" TO .090"	.060" TO .100"	.070" TO .110"	.080" TO .120"
.930 TO .945	0 TO .4	.060" TO .080"	.060" TO .090"	.070" TO .100"	.080" TO .110"	.090" TO .120"	.100" TO .130"	.110" TO .140"	.120" TO .150"
	4 TO 10	.050" TO .080"	.050" TO .090"	.060" TO .100"	.070" TO .110"	.080" TO .120"	.090" TO .130"	.100" TO .130"	.110" TO .140"
	10 TO 20	.040" TO .070"	.050" TO .080"	.060" TO .090"	.070" TO .100"	.080" TO .120"	.090" TO .130"	.100" TO .130"	.110" TO .140"
.945 TO .955	0 TO 2	.050" TO .080"	.060" TO .090"	.070" TO .100"	.080" TO .110"	.080" TO .110"	.090" TO .120"	.100" TO .130"	.110" TO .140"
	2 TO 5	.040" TO .070"	.050" TO .080"	.060" TO .090"	.070" TO .100"	.080" TO .110"	.090" TO .120"	.100 TO .130"	.110" TO .140"
	5 TO 10	.030" TO .070"	.040" TO .080"	.050" TO .090"	.060" TO .100	.070" TO .110"	.080" TO .120"	.090" TO .130"	.100" TO .140"

Land Length

Land length affects only molding temperatures and pressures. Longer land length of an orifice of a given diameter requires higher cylinder temperatures or molding pressures.

The test data indicates that the Venturi Plate will eliminate many of the problems of dry coloring polyethylene resins. The Venturi Plate is simple in design and easy to install. Quality of dispersion is very high. Pressure losses are relatively low. ★ ★

ACKNOWLEDGMENT:

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Methods for

Joining Plastics Parts

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The proper selection of a joining technique for a specific application depends upon a broad knowledge of the many available methods and of the properties required of the final assembly. The following report covers four such methods applicable to joining plastics. They have been chosen for their potential as commercial techniques and because there has been a lack of good technical information available on them.

1. **Blind Riveting**
2. **Press Fitting**
3. **Induction Welding**
4. **Spin Welding**

These techniques offer economies in assembly operations to both the processor and end-user. To the engineer and designer they offer a new approach to old problems and opportunities for new applications of his product that were formerly limited by inadequate production methods.

RIVETING WITH CHEMICALLY EXPANDED rivets is a fabricating technique just as useful for joining plastics as it has been found to be for light metal construction. Chemically expanded rivets may be used as directed for metals with most, and at least partially with all, of the plastics tested. A knowledge of related techniques and applications may suggest design innovations formerly limited by inadequate or overly expensive assembly methods.

Procedure

Industrial blind expansion rivets are fast-acting, one-piece fasteners similar in function to ordinary solid rivets, but especially adaptable in blind riveting and in hard-to-reach fastening jobs. One person working from the head side of the rivet can easily install these high-speed fasteners in two simple steps:

1. The rivet is placed in a previously drilled, punched, or molded hole.
2. The heated tip of an inexpensive riveting iron (or an approved soldering iron) is applied to the rivet head. In as little as one-half second the charge changes to a gas, expanding the shank to fill the hole completely. When expanded, the shank of the rivet forms a barrel-shaped head on the opposite side of the work to lock it permanently and securely in place.

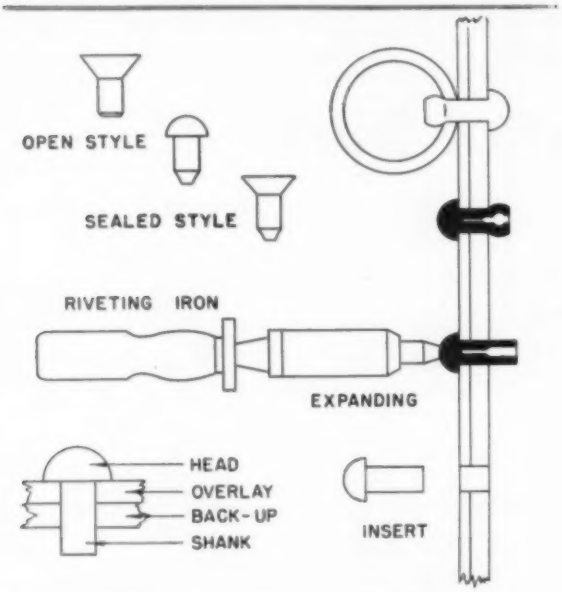
Blind expansion rivets have smooth finished heads so no buffing, trimming, or other finishing operation is usually required. The expansion of the rivet shank makes it unnecessary to observe close tolerances in molding or drilling the hole. Drilling time is reduced and insertion easier. One man can easily install these rivets at the rate of 20 to 25 a minute.

Commercial Types

Industrial blind expansion rivets are available in two types — regular rivets with the familiar open end, and a new development — sealed rivets. This new type of rivet is designed for use where the opposite or adjacent structure is very close to the expanding end of the rivet. It is practically noiseless when being set and the possibility of flash-burning adjacent surfaces is eliminated. Brass, nickel plated brass, and aluminum alloy rivets are available in several diameters (⅛" to ¼") and with a wide range of grip lengths (up to ¾"), depending on the alloy.

This paper was presented at the Fourteenth SPE Technical Conference.

Figure 1. Method of Joining Plastic Parts with Blind Expansion Rivets.



Application to Plastics

In addition to ordinary metal-to-metal, or wood to metal fastening jobs, these rivets are also being used to fasten leather, plastics, and heavy fabrics such as canvas, rubber and fiber board. The following discussion relates to the application of explosive rivets to plastics in combination with one another and with other fabricating materials.

Nylon Resin and Acetal Resin

Industrial blind expansion rivets may be used with nylon and with acetal as directed for use with metals. Rivet lengths and diameters should be chosen in the usual manner. No special care is required in preparing the rivet holes or inserting the rivets. Noticeable bulging, however, may occur when a rivet hole is located too close (less than 0.2 in) to an unsupported edge. Care should be taken in applying the heated tip of the riveting iron to the rivet head as prolonged contact with the rivet head or contact with the plastic material may cause melting or burning. Acetal and nylon may be used as either overlay or base materials, in combination with one another, and with other dissimilar materials.

Polycthylene Resin and Tetrafluoroethylene Resin

Chemically expanded rivets may be applied as directed for other materials to polyethylene and tetrafluoroethylene overlays only. Because of their relatively low elastic modulus, application as base materials is limited to low strength joints. The expansion of the rivet shank distorts most soft base materials, defeating the purpose of the rivet.

Acrylic Resin

Industrial blind expansion rivets may be applied to acrylic resin overlays as directed for other materials. As a base material in thicknesses below ¼ in., acrylic does not provide sufficient impact strength to withstand the force of the expanding rivet shank and will generally crack or split when the rivet is set. In extreme cases, shock may even be transmitted from a metal base layer to an acrylic overlay and be of sufficient magnitude to cause cracking. Altering the rivet hole size has no noticeable effect on impact resistance. As with other plastic materials, care must be taken in the application of the hot riveting tip to the rivet head to avoid burning or melting of the resin.

General Design Considerations

Where non-metallic plates are used, the strength of the riveted joint will be limited by plate strength rather than by rivet strength. The strength of the plate depends, in turn, upon the location and number of rivet holes as well as the basic properties of material used. When designing for a riveted joint stress concentrations at the edge of the rivet hole, which may be two or three times greater than the average distributed stress, should be considered. Data are given in handbooks and in technical publications on stress concentration factors to use with specific geometries.

A necessary further consideration is creep caused by long term static loading. The effect of creep, an enlongation of the rivet hole, may be conveniently calculated by employing the concept of apparent modulus in standard deformation calculations.

Post-formed holes should be made at right angles to the work surfaces. With metals, best results are obtained when burrs and chips are cleaned from between the parts to be riveted. Though less important with the more elastic plastics, these items should not be overlooked. More intimate surface contact is assured with clean interlayers. Clamping plastic sheets tightly together before drilling will prevent chipping of the surrounding surface.

The expansion of the rivet shank stresses the base and overlay materials in the area of the rivet hole. These residual stresses may have adverse effects on the impact strength and the craze resistance of a given part. These factors should be considered in designing for riveting.

Correct rivet lengths and rivet hole diameters should be chosen for plastics as directed for metal in manuals available from explosive rivet suppliers. (1)

PRESS FITTING

Press fitting is one of the oldest and simplest fabricating techniques. It is universally applicable to similar and dissimilar materials and requires no foreign elements, as cement or metal inserts, in the finished joint. Properly applied, this technique offers serviceable joints with good strength at a minimum of cost.

Interference Limits

Plastics are press fitted the same as metals and other materials, but interferences are generally increased to compensate for the relatively low elastic modulus of most plastic materials. For maximum joint strength interferences should be made as large as possible without restricting assembly or unduly stressing the part. Theoretical interference—stress level relationships are based on geometry and material properties. They may be calculated by standard stress analysis procedures employing the first equation in the Appendix which was derived from standard stress formulas (2).

Maximum interferences have been calculated by this equation for plastics at various shaft-to-hub diameter ra-

tios, assuming average environmental conditions. These data have been substantiated by experimental spot checks on all resins and by a complete test series; the resultant curves for an acrylic are shown in Figure 3. It should be noted that the indicated interferences are those at which rupture should occur.

For materials having definite yield points with a high rate of enlongation (usually at a lower stress level) thereafter, yield point data should be used in the above mentioned equation. When the yield point stress is used the indicated interference will be that which will provide maximum holding power. Interference limits for various materials based on yield point are given in Figures 4, 5, and 6. Where maximum joint strength is not required, or where ease of fitting is more important, lesser interferences may be used.

Figure 2. Press Fitting Applications.

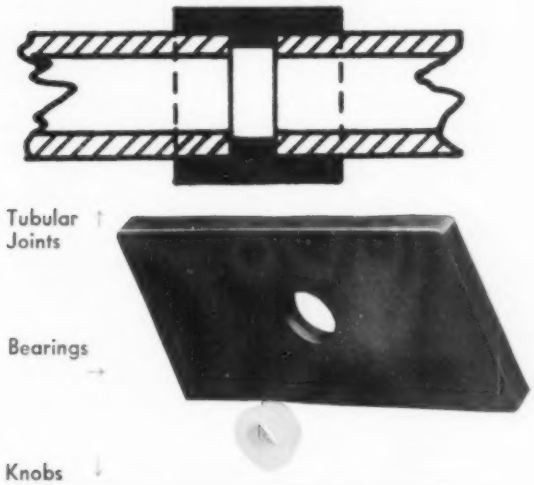
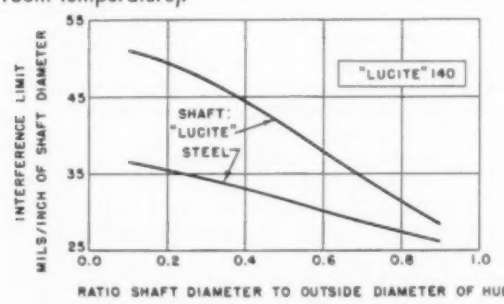


Figure 3. Theoretical Interference Limits for Press Fittings (based on ultimate strength and elastic modulus at room temperature).



Theoretical Interference Limits for Press Fittings (based on yield point and elastic modulus at room temperature).

Figure 4.

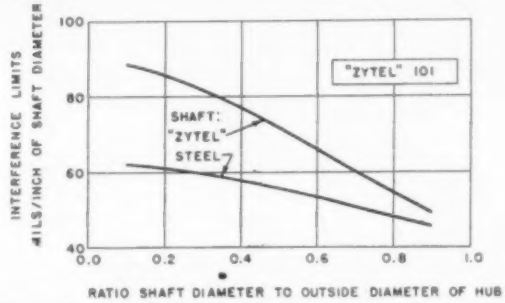


Figure 5.

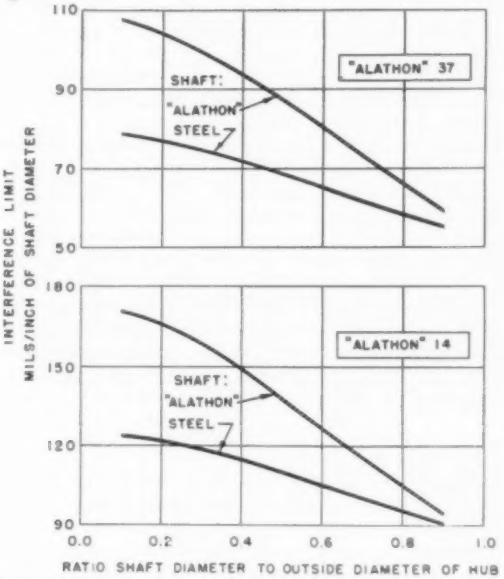
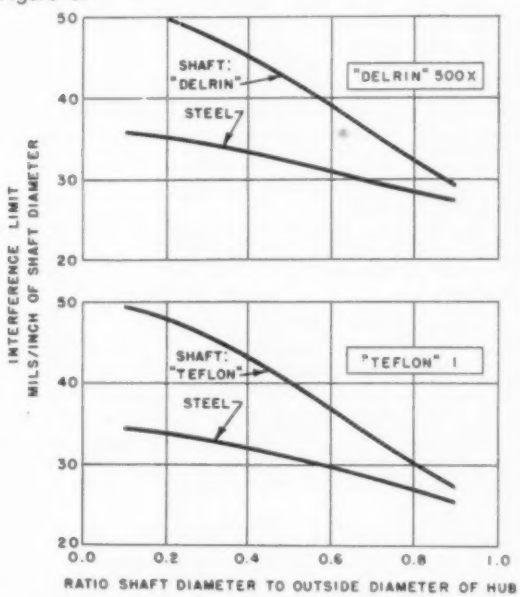


Figure 6.



Design Considerations

In most practical applications less than maximum interference will be used. For metallic inserts, as shown by equation 2 in the Appendix, the interference can be determined practically by equation

$$I = 1.25\, d_s\, S / E_h$$

where I = maximum interference (in)
d_s = insert diameter (in)
S = desired stress level (psi)
E_h = modulus of elasticity (psi)

This equation will be accurate to ± 5% over a wide range of conditions and is usually sufficiently accurate for design work. If a plastic shaft is being used then the full equation must be used.

Residual joint strength after a period of time may be determined by using the apparent modulus in place of the modulus of elasticity in the above equation. Apparent modulus is an index for predicting creep in plastics at various stress levels below their proportional limit. For most thermoplastics variation in apparent modulus becomes negligible after a year, and joint strength becomes constant at a value approximately one-half the initial strength.

Joint strength is also a direct function of the coefficient of friction between the joint surfaces. The coefficient of friction of a given material is dependent on many factors. Lubrication, moisture, temperature, and stress level are important factors, as well as surface roughness and the relative velocity of two sliding parts. Unless the change in coefficient is known for each of these conditions, calculation of joint strength will be of little value. However the coefficients of friction for average environmental conditions experiences in press fitting have been determined by experimental means for several of the plastics. These coefficients are given in Table I (See Appendix).

Axial Strength

The force required to press a hub on a shaft or to remove a hub for a shaft is given by the equation.

$$F = \pi f p d L \text{ (lbs)}$$

where
L = the length of the fit (in)
p = the unit press fit pressure between shaft and hub (determined by equation 3 of the Appendix) (psi)
f = the coefficient of friction
d = the shaft diameter (in)

Residual joint strength may be estimated for a given time after fitting by including the concept of apparent modulus when calculating joint pressure (p) in the above equation.

Torsional Strength

The torsional holding capacity of a hub on a shaft is given by the equation

$$T = Fr \text{ (in-lbs)}$$

where
r = the shaft radius (in)
F = the axial holding force as determined by the preceding equation (lbs)

When torsional properties are important, a ribbed shaft will be found effective. For axial strength rings or threads should be used. When both torsional and axial strength are required, a knurled shaft of combination of rings and ribs provides a good balance of properties.

Dimensional Changes

When a shaft is press fitted into a sleeve the outside diameter of the sleeve, as well as the inside diameter, will be expanded by the interference. Similarly, the inside diameter of a sleeve will shrink when the sleeve is pressed into a housing. The relative dimensional changes for each of these cases is of interest since these changes will affect the relative fit of parts subsequently added to the assembly or to the clearance of a bearing. These changes can be calculated by the equations 4 and 5 given in the Appendix.

Other Considerations

Knurled Shafts

The effect of a knurled shaft in press fitting has not been completely resolved, however, parts of acrylic resin press fitted with knurled steel shafts exhibit interference limits similar to, or greater than, those with smooth shafts. In test runs, gouging caused by the high spots on a knurled shaft was partially filled by plastic flow. It would appear that this relaxation of the material between the notched peaks apparently balances the effect of the stress concentration caused at the notch peak. This would indicate that interference limits may be selected in the usual manner, considering the outer diameter of the knurled shaft as the outer diameter of a smooth shaft. Cold flow into undercuts may cause joint strength to increase with time.

Shrink Fitting

The relatively high rate of thermal expansion of most plastics compared to metals can be often used to advantage in the assembly of interference fits. The dimensional change over given temperature range can be calculated from thermal coefficient of expansion data. It should be remembered that internal holes will change at equilibrium just as though the part were solid; that is, they will increase in size with an increase in temperature.

Residual Stresses

When parts are to be press fitted for maximum holding power immediately after molding they should be free of internal stresses. Internal stresses may be reduced by annealing or by the fabrication conditions used. When press fitting nylon resin moisture conditioning is usually advisable because the elastic modulus of nylon, which limits allowance interference, is greatest in the dry, as-molded condition.

Because of the high residual stresses set-up on the inner surface of a press fitted hub, notches and scratches in these areas should be avoided. Corners in key ways and other slotted areas should be rounded when possible to minimize points of stress concentration which limit allowable initial interference.

Residual stresses set up by press fitting may also promote crazing in certain plastic materials. This effect limits their exposure and chemical resistance. This factor should be considered when designing with acrylic resin.

The internal stresses in a press fitted part may reduce impact strength. It is suggested that, where a pressed part is expected to withstand considerable impact, it be tested under actual conditions to determine the feasibility of this type of joint.

INDUCTION WELDING

Induction welding is an exceptionally fast and versatile fabricating technique. It utilizes heat generated by a high frequency electrodynamic field in a resistance circuit to melt and weld adjacent surfaces. It is ideally suited for joining thermoplastics.

The induction welding technique is applied as follows:

1. A conductive metallic insert is placed on the interface of two sections to be joined in Figure 7.
2. The sections are placed within the field of a high frequency generator.
3. Pressure is applied to the sections and the field is energized.
4. Current is induced in the metallic circuit, generating heat which, in turn, melts the surrounding plastic material.
5. The field is de-energized and the melted surfaces weld together to form a strong and durable joint.

Induction welding is one of the fastest of the fabricating techniques. Some applications require as little as one second of welding time. Production speed is limited generally only by the rapidity with which parts may be set up and removed from the welding jig.

Equipment costs vary widely depending on the application. Small units may cost only a few hundred dollars, while the more elaborate induction welding generators may cost several thousand dollars.

The technique is not limited by shape or thermoplastic composition. Weld strength, however, is limited by the relatively small area in which the actual weld is formed. Welding occurs only in the area immediately adjacent to the metallic insert and very little strength can be obtained by metal-to-plastic bonding at the insert. With a properly designed insert and correct welding procedure, however, welds of considerable strength may be produced in a minimum of time.

Operating Variables

Power

Power input governs the heat up time of the insert. Cycle time is, therefore, minimized at maximum power. Power input appears to be limited only by the shortest cycle which may be controlled. Good welds have been obtained over a very wide range of machine and cycle settings. Power input is a function of many variables and generalization as to power requirements is difficult, if not impossible. Information of this nature is best obtained from induction welding equipment manufacturers and dealers.

Cycle

Heat input to the insert is a direct function of cycle time for a given power setting. More melt and consequently stronger welds will be obtained with longer cycles. However, cycle time should be only long enough to insure adequate welding, as too long a cycle may cause overheating and consequent degrading of the material. Degrading and bubbling are minimized by maximum pressure; that is, pieces under high pressure can withstand higher temperatures. Typical applications require from three to ten seconds of cycle time.

Pressure

As mentioned above, plastic materials can withstand more heat at higher pressures. That is, higher pressures will insure against degradation at a given rate of heat input. Maximum applied pressure appears to be limited only by the strength and stiffness of the welding material. In most applications a minimum of 100 pounds per linear inch of metal insert is required.

Part Geometry

The joint of a mating part should be designed so that pressure is distributed uniformly throughout, and over, the metal insert. For efficient energy transfer, the metal insert should be located as close as possible to the generator coil. A tongue and groove joint or similar configuration may be desirable to locate and hold the metal insert. In all cases the insert must be located between the plastic material faces so that no portion of the insert is exposed to air, as rapid heating and subsequent disintegration of the insert may otherwise occur.

Insert

Successful welds have been achieved by use of stamped foil inserts, standard metallic shapes as wire screen, and various configurations of conductive wire. The insert is not limited to the normal closed resistance circuit pattern. It may, in fact, be made in the shape of a star, letter, or other decorative shape as indicated in Figure 7. When wire is used, diameters ranging from 0.010 in. to 0.030 in. will be found most effective. Printed or metallized inserts may also be feasible, but they have not as yet been evaluated. When a part has been metallized for decoration, care must be taken to prevent heating and cracking of the metallized surface.

If the insert is not centered accurately within the coil, there is a tendency for the metal insert to be attracted to the coil. It is thus advantageous to design an insert-retaining groove into one section of the parts to be joined.

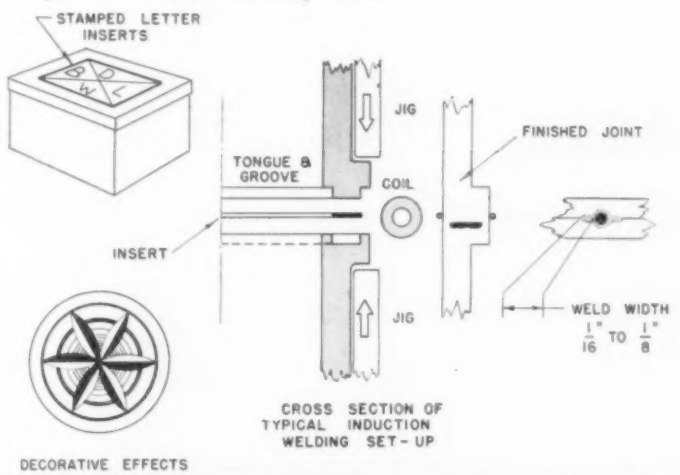
Fixtures

A clamping jig is required to obtain reproducible clamping pressures and to distribute the pressure evenly over the entire joint and insert. The jig must be in place during heating and set-up. It should be designed for rapid assembly and removal.

Safety

Induction welding equipment is generally safe; however, the energized coil should be treated with caution. Any metallic object placed within, or near, the field of the coil may become suddenly hot. Persons wearing rings or other metallic jewelry should be cautioned on the potential burning hazard, and operators should not be allowed to wear articles that are subject to inductive heating.

Figure 7. Induction Welding Process.



Equipment

Induction welding equipment should be selected through consultation with a reputable manufacturer of such equipment. A list of manufacturers and addresses can be obtained from Thomas' Register of American Manufacturers. Induction heating equipment manufacturers may also provide a source for technical assistance and information on proper coil design and location, and proper machine capacity for particular applications.

It is important to note that machine settings such as pressure, current on time, setting time, grid current, and plate voltage, must generally be determined by trial and error.

Weld Strength

With a wire screen insert between slabs of polyethylene, welds of better than 50% of parent material strength have been consistently produced. Acrylic has been processed equally well, and from all indications, welds of significant strength may be produced in almost all thermoplastics. Weld strength may be calculated by multiplying weld material strength by the area over which melt will be formed. In most cases the weld area extends 1/16 to 1/8 inch from either edge of the metal insert.

SPIN WELDING

Spin-welding is a unique fabricating method that is especially well suited for joining thermoplastics. The technique employs frictional heat that is generated by the rotational rubbing of two contacting surfaces to produce joints having exceptional quality and strength.

Specifically, the spin-welding process involves rotating one section to be welded in a powered spindle against another part which is held stationary. Rubbing contact is maintained at a speed and pressure which generates frictional heat and melts the adjacent surfaces. When sufficient melt is obtained, pressure is increased to squeeze out all bubbles and to disperse the melt uniformly between the weld faces. The stationary part is then released, or the powered spindle stopped, halting the rubbing action and allowing the weld to form. Pressure is maintained until the weld sets up. Several typical applications are illustrated in Figure 8.

In addition to the advantage of the outstanding quality of the welds produced by this technique, spin-welding offers economic advantages through speed and simplicity of operation. Standard machine shop equipment, as lathes and drill presses, may be adapted for most spin-welding jobs. With the aid of jigs and fixtures standard equipment may be converted to production units capable of joining sections with only a few seconds of welding time.

The frictional heat generated by spin-welding is of such intensity that it produces almost immediate surface melting while the temperature of the material immediately beneath the surface remains relatively unchanged. For many applications no surface preparation is necessary. A rough saw finish, in fact, can be welded into a joint of similar quality to that obtained from a machined surface.

One disadvantage of this technique is in the limitation of joint shape. The required circular shape may, however, be designed into a non-circular part and the spin-welding apparatus may be indexed to align the non-uniform part into the required final position. A possible second disadvantage is flashing which is sometimes necessary to insure complete welding. However, joint design may be regulated to minimize this flash or to trap it in internal recesses.

Operating Variables

The heat generated between two rotating, rubbing surfaces is a function of the relative surface velocity, of the contact pressure, and of the duration of contact. It is also a variable of material properties like coefficient of friction and heat transfer capacity. Experimental data indicate a direct linear relationship between the heating effect of velocity, and pressure.

Pressure must be applied uniformly to the surface to be welded. It must be great enough to force any bubbles, contamination, or degraded material from the joint. In many applications best results are obtained with an increase in pressure after initial melting. The material is thus squeezed between the joint faces as it sets up. More pressure is required at the higher temperatures to prevent degrading or bubbling of thermoplastic materials.

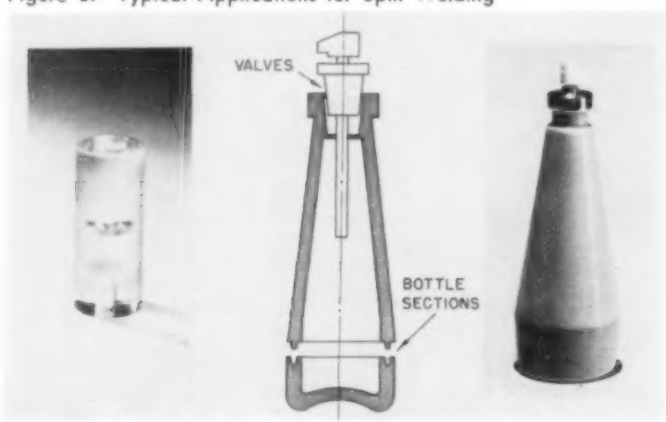
The surface velocity of a rotating cylinder is a function of the diameter of the cylinder as well as of the rpm. For a solid disc the average point velocity on the face is 2/3 the circumferential velocity. The average point velocity on the face of a hollow member is given by equation 6 in the Appendix.

The cycle should be only long enough to insure complete welding. A short cycle minimizes flash and internal stresses. In many applications one or two seconds may be sufficient for welding. Total cycle time including insertion and removal of the part to be welded is greatly influenced by the effectiveness of the jigs and adapter.

Table II indicates the approximate range of variables which have produced satisfactory welds. They should be used only as starting points from which further to determine optimum welding conditions.

The welding cycle may be controlled by any of several variables—drag, time, or axial spindle position. Position and time are the most widely used. Position regulation, which insures that a given amount of material is melted and displaced by each cycle, may be governed by a limit switch or stop. The limit switch is normally used with an automatic feed unit and an automatically disengaging adapter. When production volume

Figure 8. Typical Applications for Spin Welding



does not merit an automatic set-up, visual control may be sufficient and the rubbing may be stopped simply by shutting off the spindle drive.

Pressure control is best obtained by use of an air feed unit. Automatic feed units that may be adapted to most standard drill presses are available from several manufacturers.

Braking

Braking (stopping the relative motion of the contacting surfaces) may be critical with some plastics. Nylon and other rigid thermoplastics with a low melt viscosity and a relatively "sharp" melt-to-solid transition, must be braked almost instantaneously. When welding materials of this description, it is impossible to maintain more than a very thin film of melt between the contacting surfaces. If braking is slow, this thin film will solidify before the relative motion can be stopped and the weld will be sheared.

Joint Design

Joint geometry is the most important factor influencing weld quality. Joint design should be carefully determined. Joints should provide maximum weld area while minimizing surface velocity differential. Weld area may be increased by using step, tongue-and-groove, or taper joints. The limitation on weld area is usually wall thickness or drag created by the increased surface.

Velocity differential may be decreased by removing the center-most section of the weld area (where surface velocity approaches zero). Weld strength may be improved in small sections even if weld area is not increased to compensate for the center removal. The effect of velocity differential may also be compensated for by crowning the central area so that it melts and disperses first.

Alignment is improved with taper or tongue-and-groove joints. These joints also reduce wobble which is critical in thin walled sections (e.g. aerosol bottles).

If two compositions of a single material have slightly dissimilar melt points flash produced in welding them may be directed internally or externally. A tapered joint on a hollow cylinder will usually flash externally and not internally if the male section is of the higher melting material.

In Figures 9 and 10 are shown typical joints that have been used successfully in various applications. Relative dimensions are indicated.

Residual Stresses

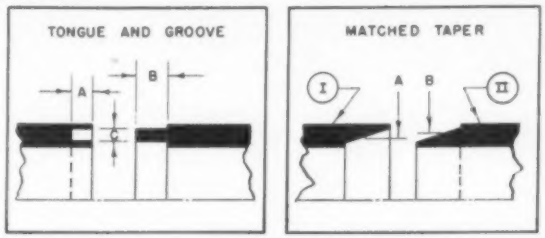
Because surface velocity varies across the face of a rotating disc, the heating pattern across the weld area of a spin-weld section will also vary. The result is trapped internal stresses. The stresses are maximum at the center of the weld and minimum at the outer surface. In the usual case, therefore, these stresses have little effect on the surface craze resistance or surface weathering qualities of a spin-welded part. However, if the more highly stressed areas of the weld are exposed to a crazing agent violent stress cracking will result. Annealing of highly stressed joints is desirable in these cases.

Control of Flash

Because molten plastic is a viscous fluid, pressure applied to it is transferred equally in all directions. Thus, welding pressure causes the melt to move in all directions from its point of origin. In spin-welding, excess melt which is forced out from between mating weld surfaces is called flashing. When the spin-welding cycle is not automatically controlled, flashing may be the best indication of complete welding, however, excessive flashing is generally undesirable and should be controlled by careful regulation of its contributing factors.

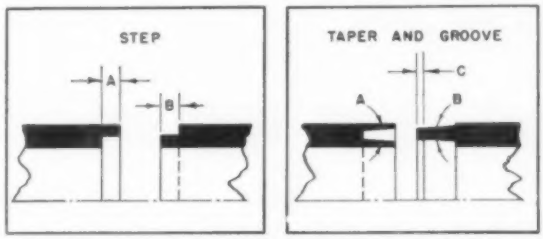
One such factor is proper joint alignment. Proper

Figure 9. Joint Designs for Spin Welding of Hollow Members.



Tongue "B" longer than groove "A". Width "C" large as possible, slip fit between "A" and "B".

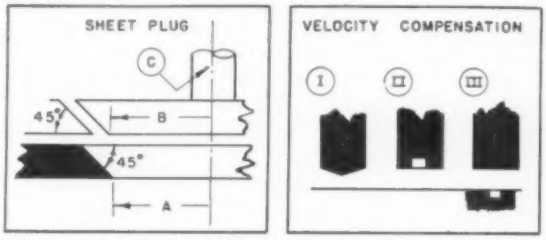
Mid point radius "B" greater than mid point radius "A". Sections I and II of different melt points for flash direction.



Slip fit between "A" and "B". Extension of "A" or "B" for initial flash direction. Width of longest step greatest.

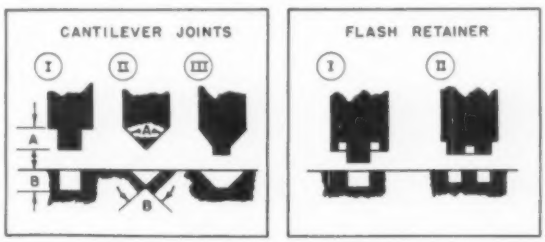
Included angle "A" slightly greater than angle "B". Small straight extension "C" on tongue "B". Tongue width large as possible.

Figure 10. Joint Designs for Spin Welding of Solid Members.



Disk radius "B" slightly larger than hole radius "A". Driving log "C" to be removed.

I. Crowned
II. Center Removed
III. Receiver



I. Extension "A" longer than receiver "B".
II. Angle "B" greater than angle "A".
III. Combination taper and receiver.

I. Internal flash retainer ring.
II. Increased joint surface.

joint alignment is effected by control of joint tolerances, by accuracy in positioning the sections to be welded in the adapters, and by the precision of the welding equipment itself. When proper alignment is achieved, comparatively little material will have to be melted and displaced to insure complete welding.

The most important factor affecting flash is joint design. Joints may be designed which will produce varying quantities of flash, internal or external flash only, or retain all flashing within undercuts and pockets included in the joints. Some useful joint designs are illustrated in Figures 9 and 10.

Control of the welding variables also affects flashing. At high speeds and pressures melt is formed and displaced faster. It is thus more difficult to control. High speeds also promote the centrifugal forcing of the melt away from the center of rotation. This increases external flashing, but acts to decrease internal flashing in hollow bodies. The amount of melt obtained, and consequently the amount of flashing, is also a direct function of cycle length. The shortest cycle that will provide adequate welding should be chosen.

Weldability

As yet, no true thermoplastic has been tested which could not be spin-welded. Resultant weld strengths, however, differ widely among the various plastic materials. The weld strength of a single material, in fact, may vary with its particular application.

An important factor affecting the weldability of a thermoplastic is moisture content prior to welding. Nylon, which absorbs a limited amount of moisture (2.5% by weight at 50% R.H. and 73°F), demonstrates this effect. Welding after drying, or immediately after molding (in "dry-as-molded" condition), results in welds with as much as ten times the strength of "wet" run nylon.

Residual stresses and heating patterns greatly affect weld strength. However, with close control of the welding variables and with proper material conditioning, welds of constant quality may be predicted and maintained. Table III indicates the approximate weld strengths obtained with typically good welding techniques on the various plastics. These values should be used with discretion and a standard safety factor included when applying them to joint design.

Applications and Special Techniques

Spin-welding may be applied to almost any assembly operation involving a thermoplastic with a circular joint. The following are only a few outstanding examples.

Hollow Members

Hollow members like aerosol bottles and plastic pipe sections are ideally suited for assembly by spin-welding. Multi-colored bottles may be produced by spin-welding injection molded sections. Bottoms and end-caps, as well as valve mechanisms may also be assembled by spin-welding. Because of the thin wall sections used in most aerosols, tapered or tongue-and-groove joints should be used to insure proper alignment and to increase the weld area.

Sheet Work

Discs may be welded into plastic sheet for repair work or to produce interesting multi-color effects. A plug with 45° tapered edges and about 1/32" diametral interference has been used successfully for applications of this type.

Filled Containers

Liquids may be sealed into thermoplastic containers by this technique. In fact, surface heating is so intense that welding may be performed beneath the surface of a liquid. Liquid filled containers completely free of bubbles may thus be simply and economically produced. This technique was used to assemble floating compasses during World War II.

Spin-Doweling

A combination of spin-welding and dowel joining provides a useful means for assembling thermoplastic sections into sizeable composites. A dowel spun through several sections welds to, and effectively becomes a part of, each of these sections, holding them together so intimately that the resultant composite may be further processed in much the same manner as a solid unit. Production time on large shapes may be significantly reduced by "spin-doweling" thin sections which require comparatively short molding cycles.

The operation is simple. Parts to be joined are first aligned and clamped on a drill press table. A hole (if not already present) is drilled through the upper sections and part way through the last. Then a dowel, slightly longer than the combined thicknesses and a few thousandths smaller in diameter than the receiving hole, is gripped in the drill chuck and spun into the opening. The dowel bottoms in the last section, generating frictional heat which causes the material in the region of the rod tip to melt and flow up along the rod surface. When the melt flashes out of the top section, the rotation is stopped and the weld is formed.

General Fastening

Spin-welding may also be used as a substitute for riveting or mechanical fastening. Flanged rods may be spun in to hold ball bearing races, gears, or other rotating members. Techniques used in spin-doweling are applicable here.

Localized Molding by Spin-Welding

Frictional heat is generated by metal to plastic rubbing, as well as by plastic to plastic rubbing. Thus, a metallic die spun against a thermoplastic, (or vice-versa), will cause melting, and by stopping the rotation and squeezing the die against the still molten plastic an exact image may be produced. The reproduction is so precise that a finely finished die will provide a polished finish in the plastic similar to that obtained by ashing and buffing. This technique is useful for finishing, labeling, and decorating standard items which are supplied to a number of users each of whom desires special identification or innovations.

Specimen Embedment by Spin-Welding

Spin-welding has been found effective for embedding metallic specimens in acrylic resin. Almost any generally symmetrical shape (gears, coins, emblems, etc.) may be quickly sealed into a protective and decorative covering by employing usual spin-welding techniques. Spin-welded embedments are of like quality to those produced by syrup casting, but do not require the lengthy polymerization period. By successively embedding part upon part, an exploded assembly display is produced.

The part to be embedded is simply placed on the flat face of the stationary section of acrylic prior to applying the rotating section to it. Initial pressure applied to the rubbing surfaces should be light. When sufficient melt is obtained fully to lubricate the area around the insert, the

pressure should be increased to squeeze out any bubbles that may appear. After welding, flash is trimmed from the weld circumference. Polishing completes the operation.

Bonding by Spin-Welding

In addition to the welding of similar thermoplastics, the spin-welding technique may be used to bond thermoplastics to plastics of different melt point and, in fact, to completely dissimilar materials. When spun against porous materials or against undercut non-porous materials, a thermoplastic will melt and flow into the cavities of the mating part. The resulting member is a strong composite having the desirable qualities of both materials.

SUMMARY

As mentioned earlier, these methods offer new approaches to assembly problems. All have been used commercially with plastics or other materials. The data and observations presented here have been given with hope that this information will help to adapt these techniques quickly and successfully to new production problems. ★★

Appendix

Nomenclature:

a = hub I.D. (in)
b = hub O.D. (in)
d_s = shaft diameter (in)
E = elastic modulus (psi)
I = maximum interference (in)
l/m = Poisson's ratio of hub, h, or shaft, s.
P = pressure (psi)
r_o = outside radius (in)
r_i = inside radius (in)
S_t = tensile strength of hub material (psi)
V = average point velocity (in/sec)
w = angular velocity (rev/sec)

$$W = \frac{1 + (a/b)^2}{1 - (a/b)^2}$$

Equations:

1. **Maximum interference:**

$$I = [d_s S_t/W] \left[\left(W + 1/m_h\right)/E_h \right] + \left[\left(1 - 1/m_s\right)E_s \right]$$

2. **Simplified equation for interference:**

For metallic shafts or inserts where the modulus is in the millions, the last term in the parenthesis above will be very small (less than 1% of the first term). For practical purposes the ratio $[(W+1/m_h)/w]$ will fall within 1.15 to 1.35, and for most conditions will be within 5 per cent of 1.25. The equation for interference then reduces to $I = 1.25\ d_s\ S_t/E_h$ and if the desired stress level is substituted for S_t then the interference at that stress level is obtained.

3. **Pressure exerted by a press-fit:**

$$P = I/[d_s(x + y)]$$

where $x = [(W + 1/m_h)/E_h]$

and $y = [(1 - 1/m_s)/E_s]$

For metalic inserts, y can be neglected. If the pressure exerted after a period of time is desired, use apparent modulus for E_h.

4. **Reduction in I.D. due to external interference:**

$$= 2\,a\,b\,I/(J + K)$$

where $J = a^2(1 + 1/m_h)$

and $K = b^2(1 - 1/m_h)$

5. **Increase in O.D. due to internal interference:**

$$= 2\,a\,b\,I/(6 + H)$$

where $G = b^2(1 + 1/m_h)$

and $H = a^2(1 - 1/m_h)$

6. **Average point velocity of a hollow cylinder:**

$$V = (2\,W/3)(F/T)$$

where $F = (r_o^2 - r_i^2)$

and $T = (r_o^2 - r_i^2)$

Table I
Apparent Coefficients of Friction for Press Fitting

Material	Pressure	Apparent Coefficient
"Zytel" 101	Below 1700 psi	0.15
to Steel	Above 1700 psi	0.09
"Lucite" 140	Below 2000 psi	0.17
to Steel	Above 2000 psi	0.14
"Delrin" 500X	Below 2250 psi	0.055
to Steel	Above 2250 psi	0.03
"Alathon" 15	Below 130 psi	0.13
to Steel	Above 130 psi	0.08

These values were experimentally determined and apply only to smooth machined, plastic to steel surfaces. They should be used only for order of magnitude estimations of joint strength and, in all cases, should be verified by use-testing of the intended application.

Table II
Suggested Range of Operating Variables for Spin Welding

Material	Average Point Velocity (Feet/Second)	Initial* Pressure (Lbs/in)
"Zytel" 101(1)	5 to 50	25 to 150
"Delrin" 500X	5 to 35	25 to 150
"Lucite" 140(2)	10 to 35	15 to 125
"Alathon" 10(3)	5 to 60	10 to 100

**In some applications, a secondary high pressure, or squeezing, after initial melting has proven beneficial in improving weld quality. This secondary pressure may be many times greater than that used to obtain initial melting, and is generally limited only by material stiffness and strength.*

NOTES:

1. *Data also applies to "Zytel" 105, "Zytel" 42, and "Zytel" 31.*
2. *Data applicable to most molded or extruded acrylics.*
3. *Data also applies to "Alathon" 14 and "Alathon" 25.*

Table III
Typical Weld Strengths Obtained by Spin Welding

		"Alathon"			"Lucite"		"Zytel"			"Delrin"
WELDED TO		10	25	37	140	130	101	105	31	500X
"Alathon"	10	95	80	85						
	25	80	90	70						
	37	85	70	95						
"Lucite"	140				85	75				30
	130				85	85				35
"Zytel"	101						70	50	55	25
	105						60	60	50	25
	31						50	50	70	30
"Delrin"	500X				30	35	25	25	30	60

Weld strengths are indicated as percent of parent material strength. Where no value is shown weld strengths were negligible, (below 10%).

These values are meant to serve only as an order-of-magnitude indication for typical applications. They may not be completely reproducible for all designs and should be used with discretion.

Ref. 1—Manual A-666 entitled—"Du Pont Industrial Blind Expansion Rivets" (Explosives Department, E. I. du Pont de Nemours & Company, Inc. Wilmington, Delaware).

Ref. 2—"Formulas For Stress and Strain," R. J. Roark, McGraw-Hill, 3rd Edition, 1954, Page 276.

Graft Polymerization on Polyethylene

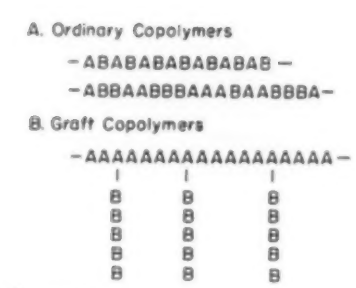


Figure 1.

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Graft copolymerization is a means of obtaining polymers with characteristics unobtainable by ordinary copolymerization methods. Ordinary copolymers may be expected to possess physical or chemical characteristics intermediate between those of polymer of each component. Graft copolymers may possess characteristics similar to one of the pure components, or they may possess entirely unique properties. Graft copolymerization also offers a means of chemically altering a preformed synthetic or natural polymer without changing its physical shape, and often without destroying many desirable properties. A hydrophilic surface might be grafted to a hydrophobic film or fiber to reduce the tendency of the material to accumulate a static charge. The grafting of selected monomers to some fabrics may improve their receptiveness to dyes. Similar treatment of plastic films may improve their printability.

GRAFT COPOLYMERIZATION can be accomplished by a number of methods, including the familiar polymerization techniques. This article deals only with grafting initiated by high-energy radiation.

Types of Copolymers

Figure 1 is an oversimplification of polymer models, but will serve to show the structural differences between graft copolymers and ordinary copolymers. For example, a vinyl copolymer may have either a regular or a random sequence. A graft copolymer, on the other hand, consists of a backbone or base of poly-A with a number of branches of poly-B. The properties of the graft copolymer will depend to a large extent on the number and length of the poly-B branches.

Initiation of Graft Copolymerization By High-Energy Radiation

Radiation-induced graft copolymerization may be accomplished by mutual irradiation or by pre-irradiation methods. Figure 2 indicates a mechanism for mutual irradiation grafting. In this procedure a polymer is irradiated in the presence of the desired monomer. The polymer-monomer combination is preferably chosen so that more free radicals are formed in the polymer than in the monomer. This situation leads to grafting. If the reverse is true, that is, if more free radicals are formed in the monomer than in the polymer, then much homopolymer-B results, and little graft copolymer is formed.

As shown in the illustration, radiation acting on the polymer may form an excited molecule which can then split into two free radicals (a polymer radical and a hydrogen atom). The hydrogen atom may then abstract another hydrogen to form hydrogen gas and another polymer radical. The vinyl monomer may then add onto the polymer radical as in normal free radical vinyl polymerization, forming the desired graft polymer.

Pre-irradiation grafting proceeds through a somewhat different mechanism (see Figure 3). In this procedure the polymer is irradiated in air. Free radicals formed by irradiation react with oxygen in the air to produce peroxide or hydroperoxide groups which are reasonably stable. Subsequent reaction of the polymer with the desired monomer at elevated temperatures results in grafting, as the peroxide groups decompose to free radicals and the vinyl monomers add on at these sites.

This paper was presented at the Fourteenth SPE Technical Conference.

Variables Involved in Radiation Grafting

A number of variables are involved in either mutual or preirradiation grafting. We have already mentioned that in the case of mutual irradiation the polymer-monomer system is preferably chosen so that, under irradiation, more free radicals are formed in the polymer than in the monomer. The extent of grafting is also dependent upon the total amount of irradiation and the intensity of the radiation. In most systems the rate of grafting is proportional to the square root of the intensity[1]. A low-energy source of radiation is usually more efficient than a high-energy source, but a longer exposure time is required. It is usually necessary to exclude air during irradiation. Even traces of oxygen dissolved in the monomer may cause significant induction periods.

Presence of inhibitor in the system causes a short period of inhibition, but after the inhibitor has been exhausted the rate of grafting is the same as that found when distilled monomer is used.

Monomer may continue to graft to the polymer after the cessation of irradiation. Ballantine[1] observed a higher degree of grafting when an irradiated polyethylene-styrene mixture was allowed to stand for a period of time up to 15 days after irradiation, than when the film was removed from the monomer shortly after irradiation. This post-irradiation polymerization may indicate the formation of "frozen-in" free radicals.

Pre-Irradiation Grafting

Pre-irradiation grafting is different from mutual irradiation grafting in a number of ways. As the preformed polymer is irradiated before immersion in the monomer, it is not necessary to be concerned about the relative rates of free radical formation of the monomer and polymer by irradiation. The irradiation of the polymer is done in air or even in dilute hydrogen peroxide solution[2]. This results in the formation on the polymer of reasonably stable peroxide or hydroperoxide groups.

The irradiated polymer is then immersed in the desired monomer. It is usually preferable to remove even the slightest traces of air from the system, as oxygen may result in inhibition of polymerization. This may be accomplished by alternate freeze-thaw cycles of the system under high vacuum. Heating is required to break down the peroxides in order to cause grafting. Temperatures in excess of 100°C. are generally employed.

The amount of grafting realized by this procedure is dependent upon a number of things, including the radiation dose on the polymer, the temperature and time of heating in the monomer, and the nature of the monomer and polymer. If, for example, the monomer has no swelling or solvent effect on the polymer, grafting will be mainly on the surface and will be limited in amount. A monomer that swells the polymer, on the other hand, may graft throughout the polymer in a very homogeneous manner. Although the grafted article usually maintains the physical shape of the original preformed article, it may grow tremendously in size.

The Use of Soft X-Rays in Graft Polymerization

The literature reports the use of many types of radiation to induce graft polymerization, including high-speed electrons and neutrons, gamma rays, X-rays, and ultraviolet rays[3,4,5]. This report will deal only with the use of X-radiation, specifically soft X-rays. The radiation source was a new prototype 60 kvp Machlett X-ray tube. The tube, shown in Figure 4, has two distinguishing features: (1) it operates on 200 milliamperes, as compared

Figure 2. Mechanism of Grafting by Mutual Irradiation.

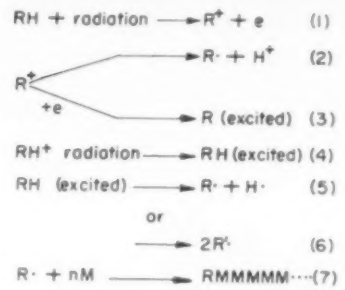


Figure 3. Mechanism of Pre-Irradiation Grafting.

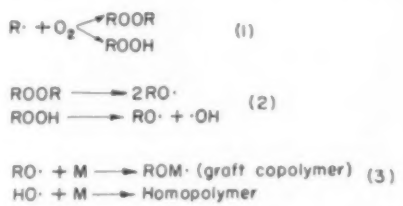
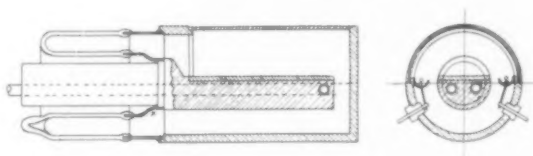


Figure 4. The Machlett Prototype X-Ray Tube.



to 30 to 40 ma for average tubes, and (2) the radiation is distributed over a 120-degree angle, instead of the typical cone shape of a conventional machine. These two factors allow production of high-intensity, low-voltage X-rays.

Calibration of the prototype tube has shown that it delivers 260,000 rep per minute at 200 ma, 60 kvp, at a distance of 4.5 inches from the tube.

The advantages of this type of tube are readily apparent. The high-intensity radiation allows relatively short exposure times, and the shape of the tube target, 1 x 4 inches, rather than a point source as in a conventional tube, causes the intensity of radiation to diminish less rapidly with distance from the tube.

The low penetrating power of X-rays has both advantages and disadvantages. Their use is limited to films or other thin sections. On the plus side, shielding requirements are minimized; one-eighth inch of lead is adequate. This is obviously much less shielding than would be required when working with gamma rays from Cobalt 60, for instance. The power supply can be readily fabricated from units generally available at an estimated cost of $5,000. A fabricator or converter could, therefore, readily install in his plant, at relatively small expense, the equipment necessary for modifying his films, fibers, or textiles by means of grafting.

Grafting of Various Monomers on Polyethylene

Acrylonitrile

In Battelle studies, acrylonitrile was grafted to polyethylene by the pre-irradiation technique. Polyethylene film was irradiated in air using the prototype Machlett tube. The film was then placed in acrylonitrile in a glass tube. The monomer was frozen with liquid nitrogen and the tube was evacuated. After several freeze-thaw cycles, the tube was sealed under vacuum, and was then heated for the desired time. After reaction, the films were washed with water and then extracted with dimethylformamide to remove any homopolymer formed. The films were dried to constant weight in a vacuum oven. The weight difference between the dried film and the original film was considered to be the amount of acrylonitrile which had been grafted. The grafting ratio, P/P_o (weight of film plus grafted monomer divided by original weight of film) was thus determined. Table I summarizes results of some of this work. It is apparent that the amount of grafting is increased, both by the radiation dose and the time of reaction in the monomer.

Figure 5 shows the same data in graphical form.

Table I

Graft Polymerization of Acrylonitrile on Preirradiated Polyethylene

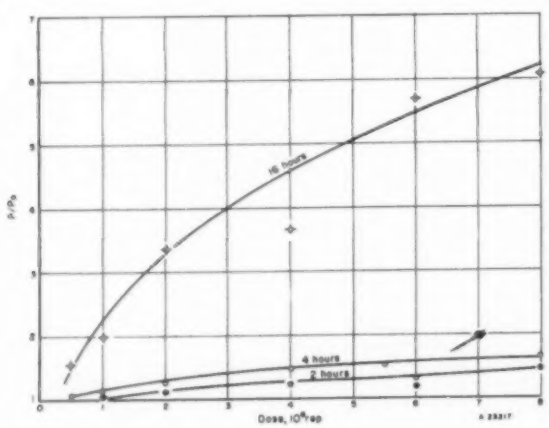
X-Ray Dose	P/P_o for Various Reaction Times at 120°C		
10^5 rep	2 Hours	4 Hours	16 Hours
0.5	0.97	1.06	1.55
1.0	1.00	1.11	1.99
2.0	1.11	1.25	3.34
4.0	1.21	1.45	3.64
6.0	1.21	1.28	5.67
8.0	1.44	1.65	6.06

Table II

Graft Copolymerization of Vinyl Acetate on Preirradiated Polyethylene
Reaction Time, 4 Hours at 120C

X-Ray Dose, 10^5 rep	Grafting Ratio, P/P_o
0.0 (Blank)	1.04
0.5	1.10
1.0	1.22
4.0	1.55
6.0	2.19
8.0	1.78
16.0	1.72

Figure 5. Grafting Ratio as a Function of X-Ray Dose, using Machlett Tube, for Acrylonitrile on Polyethylene Film.



Vinyl Acetate

Using a similar technique, vinyl acetate was grafted to polyethylene film. Homopolymer was extracted with acetone rather than with dimethylformamide. A typical set of results is given in Table II. Other samples which were reacted for longer periods were partially dissolved by the vinyl acetate. This solvent action might account for the inconsistency of the data in Table II.

Vinyl Pyrrolidone

Vinyl pyrrolidone was grafted to polyethylene film by the mutual irradiation method. The film was placed in petri dishes, and the monomer added. Assembly was done in a dry box, purged with nitrogen, to eliminate air. Mylar film, held in place by a rubber band, was used to cover the dishes.

The polyethylene film and monomer were mutually irradiated by exposure to the X-rays for the desired time. The films were then washed with water to remove unreacted monomer and any homopolymer that might have formed. The films were finally dried and weighed. The results are shown in Table III.

Table III

Graft Copolymerization of Vinyl Pyrrolidone on Polyethylene by Mutual Irradiation

X-Ray Dose, 10^5 rep	Grafting Ratio, P/P_o
1	1.00
2	1.04
4	1.63

Summary

Graft copolymerization is a means of tailor-making a polymeric molecule in order to build-in desired properties. The use of soft X-rays in graft copolymerization permits the economical treatment of thin sections, or of altering mainly the surface of thicker sections.

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PVC

Dry Blend Extrusion

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In many segments of the wire and cable industry, as well as in many non-electrical applications, the extrusion of polyvinyl chloride dry blends has grown to a large volume because of economic advantages over granulated compounds. Similar growth is probable in other areas now restricted to compounds if problems related to both materials and extrusion equipment are solved. For this reason, we have carried out extensive research to increase the knowledge of dry blend extrusion and equipment design.

This presentation includes some of the most important results of this work. It will cover differences in behavior between dry blends and compounds in the extrusion operation, indicating the variations possible in the dry blends themselves, and then show how dry blends can be extruded to attain high quality standards.

This work will also show that in order to obtain the economic advantages of dry blend extrusion, properly designed extrusion equipment is of major importance.

Although this study is based on the extrusion of wire insulation, the principles developed may be applied to other vinyl extrusion problems.

POLYVINYLCHLORIDE WIRE INSULATION formulations consist of resin, plasticizers, fillers, stabilizers, and lubricants. They are generally processed by extrusion either from granular compound or from dry blend. When a formulation is made into compound (as pellets or cubes), the milling process used to convert a wet mixture or a dry blend into compound produces enough shearing action and heat to distribute the plasticizers uniformly. This step colloids the dry blend so that a homogeneous stock is obtained, relatively free of unplasticized resin particles. The finished compound then obtains a second working during extrusion. The extruder in this case is required only to melt the compound and mix it thoroughly to form a homogeneous mass of uniform temperature.

This paper was presented at the Fourteenth SPE Technical Conference.

When the formulation is extruded directly from the dry blend stage, the extruder is required to perform two jobs. It must not only fuse the dry blend but also supply the shearing and mixing action which the milling process performs when dry blend is compounded before extrusion. Any partially or wholly unplasticized resin particles not worked out during extrusion may produce undesirable gel spots or "fish-eyes" in the extruded product. Therefore, dry blend extrusion usually requires different operating conditions and a more critical screw design than compound.

There is another difference in the behavior of dry blend and compound during extrusion; the amount of "frictional heat" developed by the two materials. Although dry blend can absorb more conducted heat from the barrel than compound because of its finer particle size, it does not develop as much heat from mechanical work. Therefore dry blend receives less total heat than compound

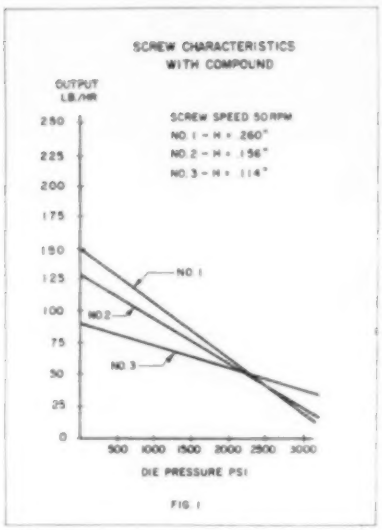


FIG. 1

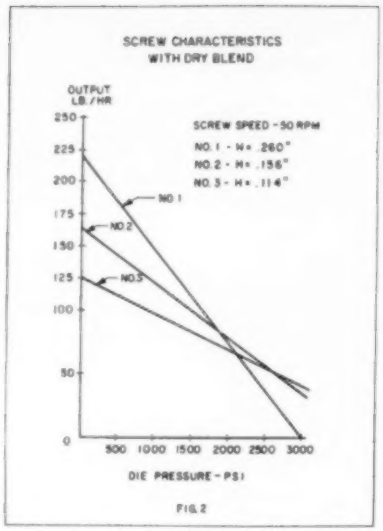


FIG. 2

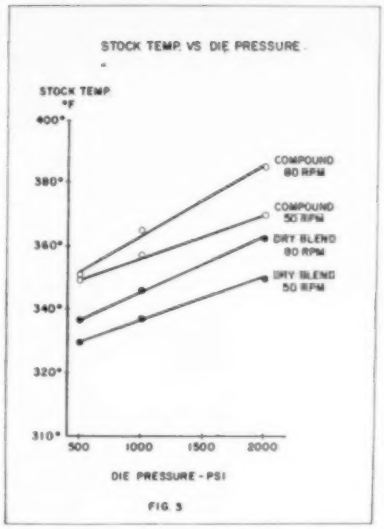


FIG. 3

during extrusion at the same machine operating conditions. It is necessary therefore to use different extrusion conditions, longer barrel extruders, shallower flight depth screw design, or increased die pressures in order to obtain equivalent stock temperatures and quality of the extruded product.

Dry Blend Characteristics

Besides basic differences between the extrusion behavior of dry blend and compound, there may be large variations in the extrusion performance of a single dry blend formulation depending on many variables in the blending operation. The end result will depend on several factors in the formulation. Especially important are the characteristics of the resin used, the filler content, the total amount and types of plasticizers, particularly whether the plasticizers are monomeric or polymeric. Just as important are the details of the blending method, including the general type of blending equipment, the addition times of plasticizer and filler, the mixing cycle, and the final end temperature of the dry blend.

It is not the intent of this presentation to cover the subject of dry blending itself, but rather to stress the major importance of this aspect. A good dry blend properly made will require less critical operating conditions and a less exacting screw design for high quality extrusion at fast rates.

The Effect of Screw Design on Product Quality

Although many mathematical equations covering screw design have been developed (1, 2, 3, 4), none of these up to the present are concerned with product quality. When extruding PVC dry blends the surface appearance and the porosity of the extruded material must be considered. Unless good product quality is obtained high extruder output is of little importance. Another complication encountered in PVC extrusion is that the material must be extruded close to its decomposition temperature if the desired physical properties of the product are to be obtained. Thus a particular screw designed to give high enough shearing action for a good extrudate can often result in excessive stock temperatures or in problems of temperature control. In contrast to plastics such as polystyrene and polyethylene, which are very stable over wide temperature ranges, PVC may degrade if a stock temperature increase of only 10°F. is encountered when operating at a desired stock temperature.

Because of these complications our work was done in two stages. The first part was an exploratory comparison of one PVC dry blend with a granulated compound of the same formulation using a range of screw designs and operating conditions. The two materials were merely extruded as a ⅛" diameter rod and the criterion of quality was the number of "fish-eyes" per gram in the extrudate. The second phase was a much more detailed study of the effects of screw design and operating conditions on **both** "fish-eyes" and porosity when using different dry blends of the same formulation. In this latter work the dry blend was actually extruded on **wire** in order to reproduce field conditions as closely as possible.

Preliminary Screw Design Comparisons

In our initial studies relating screw design to product quality, we used three screws (5) at various die pressures and screw speeds using both compound and a specially prepared dry blend which was relatively high in the number of ungelled resin particles ("fish-eyes"). This type of dry blend was selected because it represented borderline performance and would be considered unacceptable in many present day commercial extrusion operations.

A 2½ inch extruder was used with the following screws having a 16/1 L/D (length/diameter ratio) or 40 inches long.

	Screw No. 1	Screw No. 2	Screw No. 3
* h =	.260"	.156"	.114"
Constant Pitch	3⅛"	3⅜"	3 3/16"
Helix Angle	21°40'	23°15'	22°10'
Metering Section	None	None	3 Flights

* h = Depth of last flight

All increasing root diameter from feed end.

A pressure head valve (Monsanto Patent US 2,271,636 —1956) was used to obtain various back pressures on the screws (6, 7, 8). A standard indicating gauge with silicone grease was employed to measure the pressures. The output of each of the three screws with both compound and dry blend was then determined at 50 and at 80 RPM. The PVC was extruded in the form of a solid rod of about ½" diam.

Figure 4. Statistical Experiment to Evaluate Screw Design Effect on Three Dry Blends.

X — WIRE RATE, POWER, STOCK TEMP., QUALITY	SCREW	SPEED — DESIGN ↓	DRY BLEND A			DRY BLEND B			DRY BLEND C		
			60 RPM	80	100	60	80	100	60	80	100
	LONG BARREL 21-1 L/D	11/64"	X	X	X	X	X	X	X	X	X
		9/64"	X	X	X	X	X	X	X	X	X
		7/64"	X	X	X	X	X	X	X	X	X
	SHORT BARREL 16-1 L/D	11/64"	X	X	X	X	X	X	X	X	X
		10/64"	X	X	X	X	X	X	X	X	X
		7/64"	X	X	X	X	X	X	X	X	X

The compound output vs. pressure (screw characteristic) for the three screws at 50 RPM is given in Fig. 1. The screw characteristics for dry blend are given in Fig. 2. By comparing the two figures it can be seen that dry blend extrudes faster than compound at the same operating conditions with ordinary die pressures. It can also be noted that the deeper flighted screws have the greater output at the lower die pressures. Note in Fig. 2 that all three screws give equivalent production rates at about 2000 psi. We will refer to this later.

The quality of the extrudates from the three screws at the various pressures are shown in Table I. We can see that No. 1 screw with the deepest last flight (.260") produces the poorest quality with dry blend while No. 3 screw with the shallowest flight produces the best quality (fewest "fisheyes" per gram). It can also be noted that as the die pressure is increased the quality improves with all three screws. However at 2000 psi. back pressure all three screws begin to produce at about the same quality. Since the three screws have nearly the same output at this back pressure (Fig. 2), the stock is receiving about the same dwell and working time in the extruder for each screw. With deeper flighted screws, higher die pressures are necessary to obtain suitable quality but with a greater sacrifice in output than for a shallower flighted screw.

Table I also shows that all three screws produce good quality when extruding **compound** even up to 80 RPM and at **low** die pressures.

Fig. 3 shows the effect of die pressure on stock temperature and also shows that compound develops more heat than dry blend. The stock temperatures of dry blend even at 80 RPM screw speed are lower than compound at only 50 RPM.

Thus far we have shown that screw design is more critical with dry blend than with compound and that back pressure should be considered when designing a screw for a certain job. We have also shown that dry blend will extrude faster than compound with the same screw and at the same operating conditions, but the quality of the extruded product may not always be acceptable.

Detailed Screw Design Comparisons

Based on the preliminary results six screws were designed and conditions selected for further evaluation. A complete factorial experiment of 54 tests (Fig. 4) was carried out which involved three dry blends of the same formulation taken to three different end temperatures. These were extruded on No. 14 copper wire as a 1/32" insulation using three different screw speeds with three long screws (21-1 L/D) and three short screws (16-1 L/D). A standard crosshead wire die was used with a 2½" extruder.

The following variables were measured:

1. Output - Wire rate (ft./min.)
2. Stock Temperature
3. Power Input
4. Quality
   (a) Porosity in Insulation (See Appendix for Test Method)
   (b) Insulation surface ("fish-eyes")

The three screw designs for each of the two barrel lengths are given in Table II.

Results

The results of this factorial experiment are as follows:

1. **Output - Wire Rates:**

Fig. 5 shows the output of each screw design for both short (16-1 L/D) and the long (21-1 L/D) extruders. Each plotted point is the average of 9 wire rates obtained with the three different materials at three different screw speeds. With the long barrel, the shallower flighted screws (9/64" and 7/64") gave a greater output than the 11/64" screw. This could be due to differences in screw characteristics at the die pressures used in these tests. The 9/64" long screw produced the highest output.

Fig. 6 shows the output versus screw speed for both extruder lengths. Again each point is the average of 9 wire rates (three materials with three different screws). The wire rates increase with screw speed and the longer screws outproduce the short screws.

Fig. 7 shows the output against the grade of dry blend. The change in output between the different

TABLE I
● QUALITY OF THE EXTRUDATE

	SCREW SPEED	DIE PRESS	NO 1 SCREW h = .260" QUALITY	NO 2 SCREW h = .156" QUALITY	NO 3 SCREW h = .125" QUALITY
DRY BLEND	50 RPM	500#	2000+	400	150
"	50 "	1000#	1000+	280	15
"	50 "	2000#	6	10	1
DRY BLEND	80 RPM	500#	----	440	160
"	80 "	1000#	----	300	40
"	80 "	2000#	----	9	2
COMPOUND	50 RPM	500#	1	2	1
"	50 "	1000#	0	0	0
"	50 "	2000#	0	1	1
COMPOUND	80 RPM	500#	2	0	1
"	80 "	1000#	0	1	1
"	80 "	2000#	0	0	0

● QUALITY = MEASURE OF NUMBER OF FISH EYES PER GRAM OF EXTRUDED STOCK
— PSI

Table II

	Short			Long		
	40"	16-1 L/D		52.5"	21-1 L/D	
* h	11/64"	10/64"	9/64"	11/64"	9/64"	7/64"
1st flight depth	7/16"	7/16"	8/16"	7/16"	7/16"	7/16"
Constant pitch	3 3/8"	3 3/8"	3 3/16"	3 3/8"	3 3/8"	3 3/8"
Compress. ratio	2.6-1	2.8-1	4-1	2.6-1	3.1-1	4-1
No. flights in Metering section	2	3	3	4	4	4

* h - Flight depth in metering section
All with increasing root diam. from first flight to metering section.

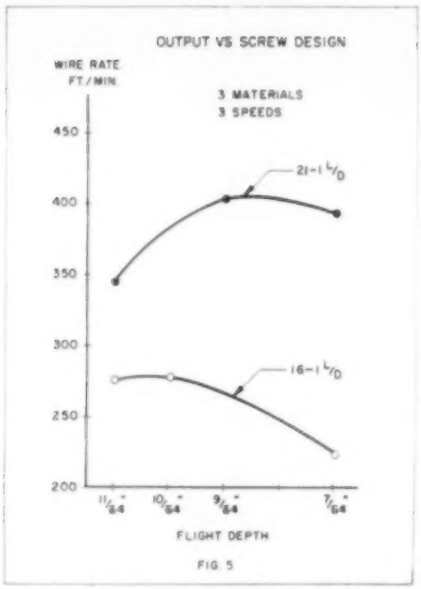


FIG. 5

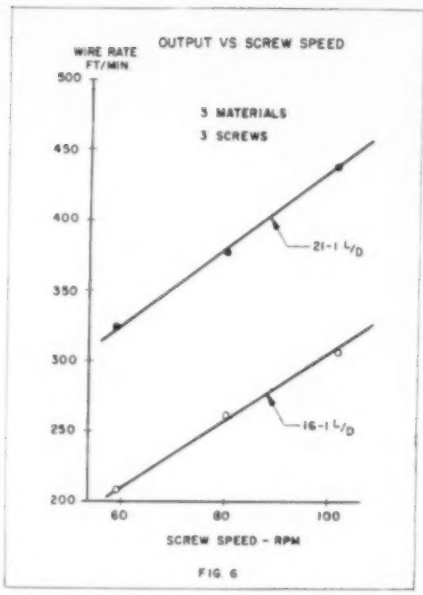


FIG. 6

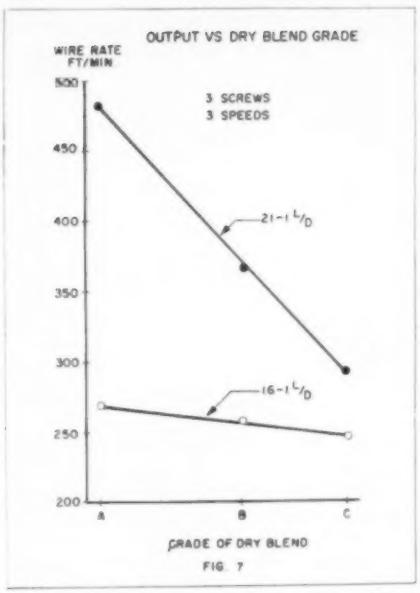


FIG. 7

dry blends is much greater with long screws than with the short. Dry blend A (lowest end temperature) extrudes much faster than dry blend B or C with the long screws.

At this point, if we consider output only we would select the long screw with the 9/64" metering section and dry blend A which would give the highest wire rates. At 100 RPM screw speed and with dry blend A, this screw extruded at 580 ft/min. or 215 lb./hr. of PVC.

2. **Stock Temperature:**

Fig. 8 shows that the stock temperature increases with screw speed. Both the short barrel and the long barrel stock temperature results are averaged together. Unfortunately we can not compare the short barrel stock temperature results with those of the long barrel because we used lower temperature settings with the long barrel. This was done to reduce the possibility of obtaining excessive stock temperatures when we reached 100 RPM with the shallowest flighted long screw.

Fig. 9 shows the effect of screw design on stock temperatures. Stock temperature increases as the screw flight depth decreases. The temperature settings for the long and those for the short barrel respectively, were held constant during all test runs.

3. **Power Input:**

Fig. 10 shows the power input at the different screw speeds for both extruder lengths. Although several tests made previously with other dry blends had shown about 35% power increase for the long screw versus the short, in this case the power required for the long barrel was not substantially different

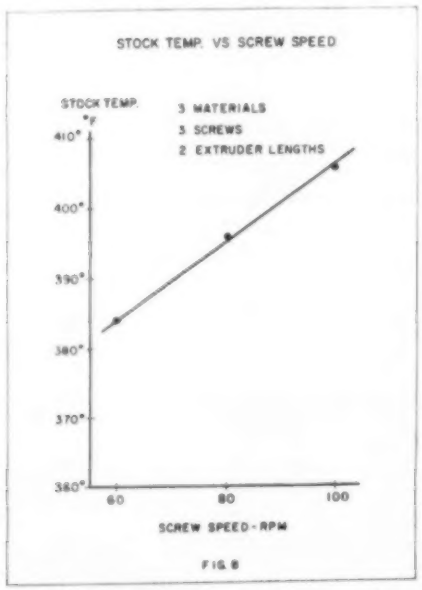


FIG. 8

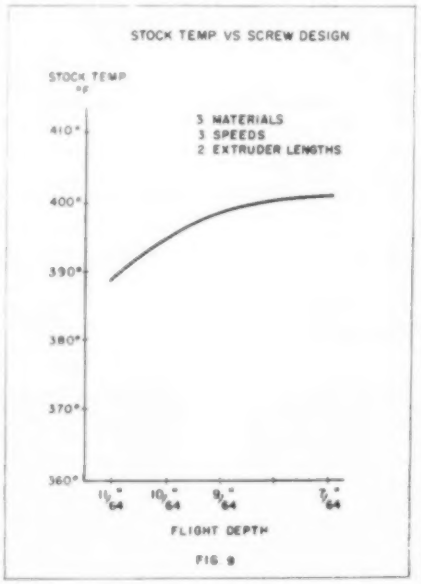


FIG. 9

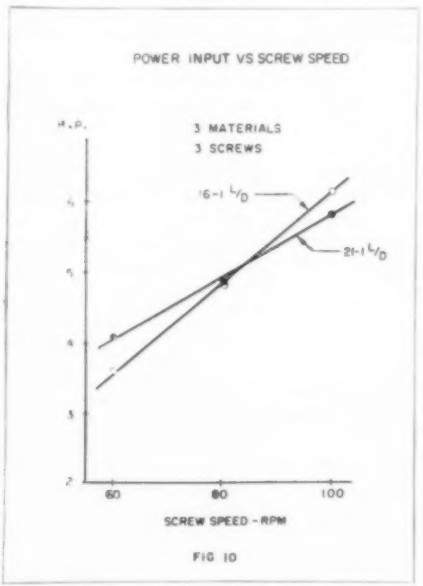


FIG 10

than that for the short. This is probably again due to the different barrel temperature settings used during the tests with the long and the short barrels. It is generally agreed that additional power should be made available for the longer extruders.

4. **Quality of the Wire Coating:**

(a) **Porosity:**

Porosity in wire insulations is a greater problem with dry blend extrusion than with compound. A unit volume of dry blend contains more free air than a unit volume of compound. The air is more widely distributed and entrapped between the resin and filler particles in the dry blend. Therefore it is more difficult to eliminate the air from dry blend than from large compound pellets as they are compressed from the solid to the melt state during extrusion. With the same screw and the same operating conditions the melt zone for a dry blend will usually be nearer the die than for compound. At higher screw speeds when the dry blend melt zone moves too near the die opening, air is carried through by occlusion. This also can occur when compound is extruded at high rates and especially at low die pressures as with cable jacketing. Water as absorbed moisture in either dry blend or compound can also cause porosity and should be removed before extrusion. This definitely will eliminate one source of porosity. In our tests we did not have to contend with moisture but only with the air in the dry blends.

Fig. 11 shows the porosity or percent air volume in the extruded insulation versus screw speed. The short barrel screws produce more porosity than the long screws especially at higher screw speeds. Averaging the 27 test results for the long barrel (3 materials, 3 speeds, 3 screws) and comparing with the same number of test results for the short barrel, the long screw produces 5.7% average porosity versus 7.4% for the short screw. It should be noted that the lower average porosity value with the long screws was obtained even at considerably higher outputs than with the short screws.

Fig. 12 shows the porosity versus the grade of dry blend used. The X point on the curve will be explained later. Dry blend A gave very little porosity regardless of screw design, screw speed, or extruder length while dry blends B and C produced larger amounts. We knew that the manner in which the dry blends were made would produce different amounts of porosity in the wire coating. But one of the main purposes of these tests was to determine how effectively porosity would be eliminated from dry blend extrusion by use of a single stage extruder with different screw designs. We can also see how important the dry blending method can be in preparing a dry blend for extrusion with respect to potential porosity. It should be noted however, that not all formulations are as sensitive to dry blend preparation with respect to porosity. As for the presence of porosity in insulations, our data to date do not indicate any noticeable effect on specific inductive capacitance (SIC), elongation, tensile, or modulus values for porosities under 10%.

We are presently working with vented extruders which appear to be one solution to eliminating porosity during dry blend extrusion. A

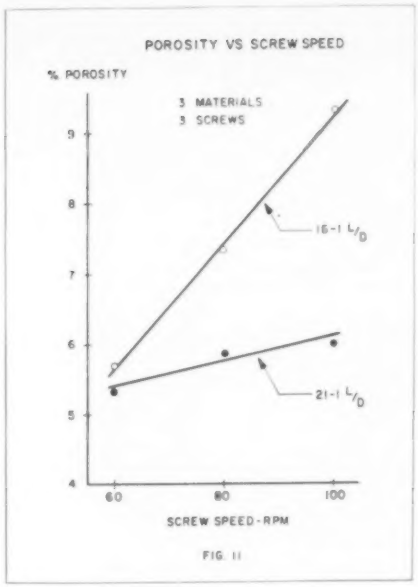


FIG. 11

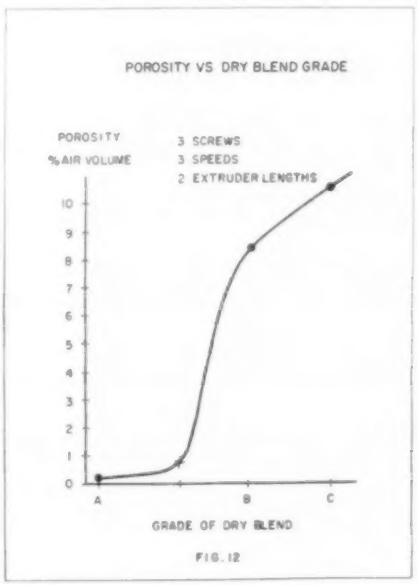


FIG. 12

vented extruder is capable of removing moisture as well as air or other volatiles in the dry blend. Although our tests are not complete, there are indications that the vented extruder will find its way into the wire coating field for dry blend extrusion.

(b) **Surface Appearance of Insulation:**

All of the coated wire samples were graded for surface appearance first by visual observation and rated as Good, Fair, or No Good. Then the number of "fish-eyes" per gram was determined on samples of the stripped insulations. Table III shows a summary of the results.

None of the three long screw designs produced acceptable surface quality with dry blend A. They did produce good quality with dry blends B and C. The three short screws did

much better (from a quality standpoint) with dry blend A and had no difficulty with B and C. However this does not mean that the short screws are better than the long as will be shown later. The above "fish-eye" quality results again showed the effect of using different grade dry blends even of the same formulation. As was expected, dry blend A gave poor surface quality and low porosity while dry blends B and C gave good surface but higher porosity. The desirable solution to this problem would be to make a dry blend somewhere between A and B. When such a blend was made and extruded with the long 9/64" screw, the porosity result shown at the X point in Fig. 12 was obtained. But since there may be times when one might be faced with a blend like A, we ran further tests with dry blend A.

It was known that the quality of the extrudate when extruding dry blend A with the long screws could be improved by the use of screw cooling water. This would reduce extrusion rate but the longer screw would still out-produce the short screw. The results of these tests are given in Table IV. It can be seen that when the long screw reached acceptable quality (low "fish-eyes") by the use of cooling water, its output was still greater than that of the short screw.

TABLE III
SURFACE QUALITY OF THE INSULATION

	DRY BLEND A	DRY BLEND B	DRY BLEND C
(11/64"	* 232 (NG)	5 (G)	4 (G)
21-(9/64"	547 (NG)	0 (G)	2 (G)
L/D(7/64"	197 (NG)	0 (G)	0 (G)
(11/64"	9 (F)	0 (G)	0 (G)
16-1 (10/64"	5 (G)	1 (G)	0 (G)
L/D(7/64"	2 (G)	0 (G)	0 (G)

* AVERAGE NUMBER OF FISH EYES PER GRAM FOR 3 SPEEDS (60,80,100 RPM)

VISUAL GRADING — NG – NO GOOD
F – FAIR
G – GOOD

TABLE IV

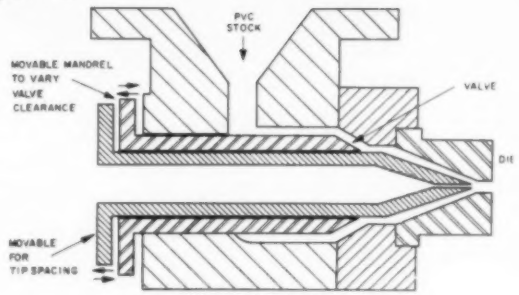
SCREW	SCREW COOLING WATER	WIRE RATE FT./MIN	QUALITY FISH EYES	% AIR VOLUME POROSITY
9/64" LONG	90°F	580 FT	400 (NG)	0.50%
9/64" LONG	60°F	400 FT	6 (G)	0.22%
10/64" SHORT	90°F	360 FT	6 (G)	1.00%

TABLE V
CROSSHEAD DIE VALVE TESTS
9/64" LONG SCREW — DRY BLEND A

SCREW RPM	DIE PRESS	WIRE RATE FT./MIN	FISH EYES PER GRAM	INSULATION SURFACE APPEARANCE
40	2150	318	84	NO GOOD
40	2550	306	64	NO GOOD
40	3000	221	0	GOOD
80	1800	434	21	NO GOOD
80	2500	372	0	GOOD
80	3000	313	0	GOOD
100	2000	484	2	GOOD
100	2500	413	0	GOOD
* 100	11/64" SHORT SCREW	360	6	GOOD

* INCLUDED FOR COMPARISON – REGULAR EXTRUSION CONDITIONS, NO VALVE.

Figure 13.



SCHEMATIC DRAWING
VALVE IN CROSSHEAD DIE

Since our earlier screw characteristic tests had shown the effect of die pressure on product quality, there was another way of up-grading the end quality of dry blend A with the long screw. A valve was installed in the crosshead wire die so that the back pressure on the screw could be varied (Fig. 13). The 9/64" long screw was again used. The quality results and the extrusion rates are given in Table V. It can be seen that by the use of higher back pressure and screw speed the 9/64" long screw produced at 484 ft./min. (180 lb./hr.) with good quality ("fish-eyes" and porosity) versus 360 ft./min. (134 lb./hr). with the short screw at the same quality. These last results show how a relatively poor dry blend can be extruded satisfactorily by use of other machine design aspects besides screw design.

We do not wish to leave the impression that the majority of dry blends that are made for direct extrusion are as difficult to extrude as the A dry blend used in this investigation. The formulation as indicated previously was purposely selected in order to accentuate variables affecting dry blend extrusion. Most dry blend formulations are less critical and will give good quality and high extrusion rates under a wider range of conditions and equipment variables.

Conclusions

1. The quality of extruded dry blend is affected by the blending method used to prepare the dry blend for extrusion.
2. The best screw design for the extrusion of PVC dry blend has shallower flights than that for the extrusion of PVC compound.
3. The quality of PVC extruded from dry blends can be improved, at equal output, by increasing both die pressure and screw speed. Screw cooling water can also be used to improve quality within limits as is generally known.
4. The use of long barrel extruders can increase dry blend extrusion rates 30-40% above that of short barrels with less porosity and better surface appearance.
5. It is believed that vented extruders will be used more and more to eliminate the porosity problem so that dry blend preparation can be less critical.

Appendix

POROSITY is reported as percent air volume in the insulation. This was obtained by weighing 10-12" of stripped insulation in air and then in water to obtain the

(Please turn to page 72)

Epoxy Casting Resins for Electrical Applications

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This paper describes test methods which were used in selecting epoxy casting resins for electrical applications. Typical applications included potting and encapsulation of units such as toroids, transformers, resistors, and capacitors. Among the requirements considered essential for a resin system to be used for electrical applications were the following:

1. High electrical resistivity
2. Thermal shock resistance
3. Low dissipation factor
4. High heat distortion temperature
5. High degree of thermal ability (low volatile loss)

Additional requirements which were investigated, but will not be discussed were the following:

1. Low viscosity for thorough impregnation
2. Low volume shrinkage during polymerization; no after shrinkage
3. Low thermal coefficient of expansion
4. Low moisture absorption
5. Good adhesion to metals, ceramics, and plastics
6. Low exotherm; low temperature curing
7. High heat dissipation
8. Non-corrosive to metals
9. Capability of withstanding extreme mechanical shock conditions

A large number of epoxy resins and curing agents were available; combinations of these resins and curing agents produced a wide variety of cured resins differing primarily in type and degree of cross-linking. In order to select a casting resin appropriate to the application, various electrical and thermal properties of representative systems were measured.

I. Electrical Properties

The following electrical properties were measured: 1) dissipation factor at elevated temperatures, and 2) insulation resistance at elevated temperatures.

A. Dissipation Factor

Materials used for electrical insulation should generally have low power losses in order to reduce the heating of the material and to minimize its effect on the rest of the network.

1. Test Method

The resin systems under test were cast in a mold which consisted of two ⅜" x 6" x 6" steel plates, with a 1/8" thick U-shaped spacer of "Teflon". The resin-hardener systems were prepared and poured into the preheated mold, care being taken to avoid the entrapment of air. The materials were then cured according to the cycle specified for the given system. The specimens were sanded to a final size of 1/8" x 4" x 4". The specimens were placed between two electrodes in a mechanical convection oven. Grounded capacitance measurements were made at elevated temperatures with a Western Electric Impedance Bridge No. D178448, a sensitive indicating detector, and an Hewlett Packard Audio Oscillator with a range of 20 cps to 200,000 cps. This test was a modification of ASTM D150-54T and MIL-I-16923B.

Dissipation factor was calculated from the formula: $D = G/W\ C_p$
where G = conductance in mhos
C_p = capacitance in farads
$\omega = 2\pi x$ frequency (cps)

2. Results

The effect of cure cycle was shown by the dissipation factor values of Epoxy A and an amine complex of boron trifluoride. Curve (a), Figure 1, shows this system after a minimum cure of 3 hours at 100°C., followed by 3 hours at 135°C.; the curve exhibits a minimum at 35°C. to 45°C. Further curing, 24 hours at 150°C., shifted the dissipation factor minimum to a 95°C. to 110°C. range, Curve (b), Figure 1. The lower temperature value observed with a minimum cure may be due to an excess of unbound polar groups as furnished by unreacted hardener.

Figure 2 illustrates the effect of two different hardeners on dissipation factor at elevated temperatures. A minimum value was exhibited at different temperatures, dependent upon the hardener used. This minimum dissipa-

This paper was presented before the recent SPE RETEC sponsored by the New England Sections at Lowell Institute of Technology.

tion factor value was observed at a higher temperature for the system known to have better high temperature properties. A difference in the minimum dissipation factor range at elevated temperatures may be attributed to the difference in motion of polar groups at the edges of large cross-linked molecular chains. It was postulated that resins which exhibit a minimum at a lower temperature were more susceptible to molecular rotation than the higher temperature minimum types; this may also be a manifestation of the amount of cross-linking in the solidified resin. These results indicated that dissipation factor measurements at elevated temperatures may be a valuable analytical tool for determining such critical variables as cure cycle and hardener type.

B. **Insulation Resistance**

Insulating materials are used in general to provide electrical protection and mechanical support to components of an electric network. To fulfill the electrical requirements, it is generally desirable to have the insulation resistance as high as possible, consistant with acceptable mechanical, chemical and heat-resisting properties; although, in many cases insulation resistance need be only high enough to have no appreciable effect on the operation of the network. Since insulation resistance combines both volume and surface resistance, its measured value is strictly applicable only when the test specimen has the same form as is required in actual use.

1. **Test Method**

Specimens of each resin system were cast in molds with five wire terminals, and five ⅛" tinned strips, each type of terminal being embedded at intervals of ¼", 3/16", 1/", and 1/16". "Teflon" insulated lead wires were clamped to the terminals. This test was a modification of ASTM D257-54T.

The above specimens were placed in an oven and the lead wires passed out the top opening. The temperature has held constant for ½ hour, at each temperature interval, and readings of resistance were taken between the various terminals with a Beckman Ultra-ohmeter. The temperature was raised from 85°C, in steps to 209°C. The average resistance between the 1/16" wire terminals versus the temperature was plotted. (Figure 3)

2. **Results**

The insulation resistance was lowered with an increase in temperature. The various resin systems caused the insulation resistance to vary widely. (Figure 3)

II. Thermal Properties

A. **Heat Distortion**

The heat distortion temperature indicates the resistance of the cured resins to mechanical stress at elevated temperatures.

1. **Test Method**

The heat distortion temperature was measured with an American Instrument Company Heat Distortion Tester according to ASTM D648-45T. The specimens were subjected to 264 psi's fiber stress and a rate of temperature rise of 2°C. per minute.

The temperature at which the specimen deflected .010 inches was reported as the heat distortion temperature. Test specimens were cast in a steel mold to a size of 0.5" x 0.50" x 5.0".

2. **Results**

A wide range of heat distortion temperatures were obtained; values varied from 79°C. to 180°C., depending on curing conditions and materials used. (See Table 1)

B. **Volatile Loss**

The volatile loss test is a modification of ASTM D1293-52, and is a measure of the weight loss of a plastic sample at elevated temperatures.

Figure 1. Dissipation Factor: Effect of Varying Cure Cycle. Epoxy-Amine Complex of Boron Trifluoride. Measured at 100 KC.

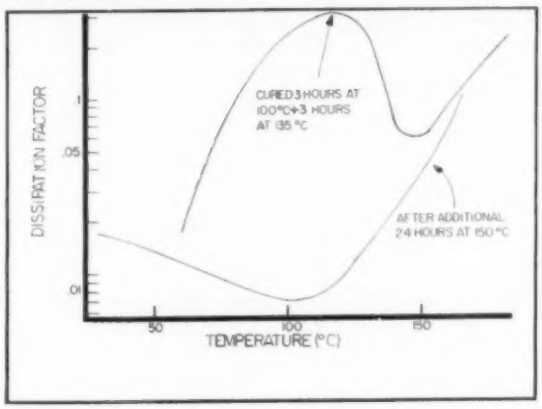


Figure 2. Dissipation Factor: Effect of Hardener Measured at 100 KC.

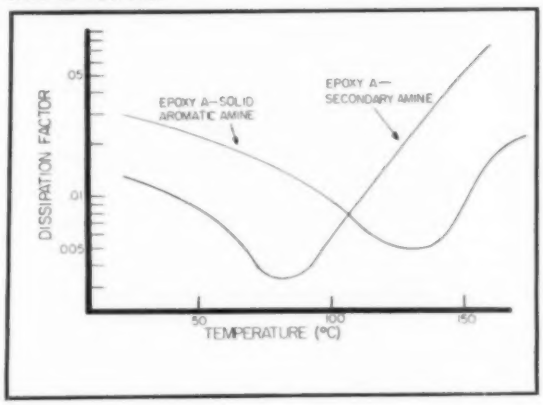
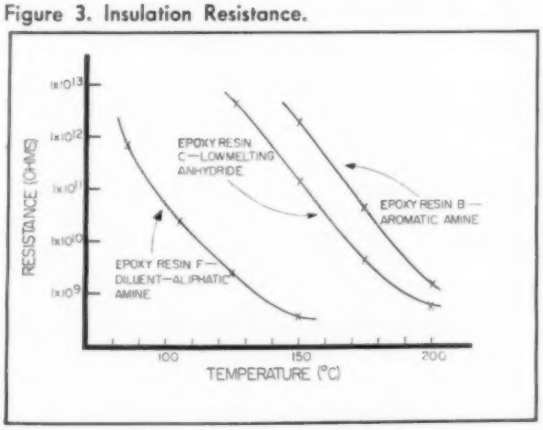


Figure 3. Insulation Resistance.



1. **Test Method**

Three 30-gm specimens of each hardener system were prepared and cast in 2" aluminum foil dishes. The specimens were weighed on the analytical balance and placed in 600-ml beakers so that each sample was surrounded by activated charcoal. The filled beakers were placed in the oven for the specified time at a temperature of 150°C. The samples were removed after 24 hours, allowed to cool,

Resin System	Cure	HDT (°C)	Post-Cure	HDT (°C)
1. Epoxy A with liquid aromatic amine A	3 hrs— 65°C	81	3 hrs—135°C	149
2. Same as 1	2 hrs—80°C		2 hrs—150°C	156
3. Epoxy A with liquid aromatic amine B silica filled	3 hrs— 65°C 3 hrs—175°C	142	24 hrs—150°C	149
4. Epoxy A with solid aromatic sulfone	14 hrs—135°C	99	24 hrs—200°C	180
5. Epoxy E	3 hrs—125°C	112	16 hrs—200°C	135
6. Epoxy A with solid aromatic amine A	2 hrs— 80°C	112	24 hrs—150°C	134
7. Epoxy D	7 hrs—140°C	79	24 hrs—200°C	96

Table I

Heat Distortion Temperatures

Table II

Volatile Loss at 150°C

Resin System	24 Hrs % Wt Loss	240 Hrs % Wt Loss
Epoxy A with liquid aromatic amine A	.11	.33
Epoxy A with liquid aromatic amine B	.12	.61
Epoxy A with liquid aromatic amine C	.18	.45
Epoxy A with liquid aromatic amine D	.12	.84
Epoxy A with solid aromatic amine A	.03	.06
Epoxy A with boron trifluoride amine complex	0	.05
Epoxy A with amine salt	.08	.37
Epoxy A with secondary amine	0	.08
Epoxy C with low melting anhydride	0.12	0.19
Casting Resin F	10.2	---

brushed free of carbon, and reweighed. The percent weight loss was calculated from the formula:

$W_1 - W_2 \times 100 / W_1 = \%$ weight loss

where W_1 = initial weight

W_2 = weight after heat aging

The samples were returned to the oven to complete 240 hours total residence, reweighed, and percent volatile loss for 240 hours calculated as above.

2. **Results**

The volatile loss was reported for the specified temperature for both the 24 hour and 240 hour exposures. (Table II) Volatile loss tests were an indication of the degree of thermal stability and aging characteristics. (See Figure 4)

C. **Thermal Shock**

A thermal shock test is a measure of the resins ability to withstand extreme temperature changes.

1. **Test Method**

A cylinder of resin, 2 inches diameter and 1 inch high, was cast with seven ¼" aluminum rods imbedded to within 1/8" of the bottom. The rods were spaced at increments of 1/32", 1/16", 1/8", 3/16", 1/4", and 3/8" apart and also spaced at increasing increments from the outside circum-

Table III

Thermal Shock Test

Resin System	Cycles (*) Passed Before Failure
Epoxy A with secondary amine	4 samples passed 0
Epoxy A with amine salt	4 samples passed 0 1 sample passed 3
Epoxy A with solid aromatic amine	4 samples passed 10
Epoxy B with solid aromatic amine	1 sample passed 10
Epoxy A silica filled with liquid aromatic amine A	4 samples passed 10
Epoxy C with low melting anhydride with tertiary amine accelerator	1 sample passed 0 1 sample passed 0
Epoxy F with diluent and aliphatic amine	2 samples passed 0
Epoxy B with a polyamide curing agent	2 samples passed 0
Epoxy A with an amine salt modified with a polysulfide polymer	2 samples passed 0

(*) *1 Cycle: 30 min. at 105°C followed by 10 min. at −55°C*

Figure 4. Volatile Loss Test at 150°C.

Above. Resin F after 24 hours.

Right. Resin A after 240 hours.

Figure 5. Thermal Cycle Test and Mold Assembly.

ference starting with the close spaced rods (1/64", 1/32", 1/16", 1/8", 3/16", 1/4", and 3/8").

After complete cure, these castings were subjected to a thermal cycle of 105°C. for ½ hour and -55°C. for 10 minutes. This cycle was repeated until the castings exhibited cracking or the completion of 10 cycles, as given in MIL-I-16923B.

2. **Results**

Table III shows that solid aromatic amine hardened resins withstood the thermal shock test, while the remaining resin systems, including certain flexible types, failed. This test gave an adequate comparison between resin systems for resistance to thermal shock. Each application should be tested individually; a resin passing the above test may not pass for an application which has a completely different configuration.

III. Applications of Epoxy Casting Resins

The preceding tests aided in selecting a general purpose casting resin; however, each application required special consideration.

Three of the most difficult application problems which were resolved were as follows: 1) overcoming the effect of thermal shock cracking, 2) overcoming the effect of pressure during cure on pressure sensitive parts, and 3) overcoming the effect of high temperature during cure on heat sensitive components.

Design considerations which helped to overcome the effects of thermal shock were as follows: 1) sharp edges and corners on metal inserts were eliminated, and 2) large embedded metal parts were cushioned with flexible foam, silicone rubber, or plastisol.

Pressure sensitive parts, such as C-cores, E or I laminations with critical gap spacing, and ferrite cores were sealed and cushioned so that pressure from the curing resin could not move them.

Heat sensitive components required a low-exotherm, low-temperature curing resin.

Figures 6 and 7 show design techniques used on a high voltage transformer which was designed to operate at 120°C. A special "Teflon" sheet, surface treated to gain adhesive to epoxy resin, was utilized as the layer insulation along with epoxy coil forms; this helped make the coil unit more resistant to high voltage arcing. The casting resin used was an unmodified epoxy resin, silica filled, and

(Continued on page 57)

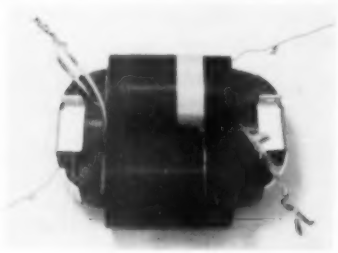


Figure 6. (left)
100 KV Pulse Transformer
before encapsulation.

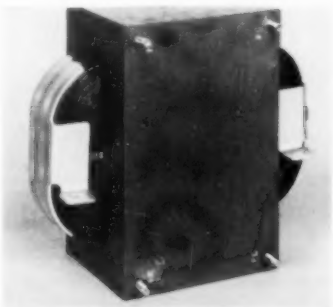


Figure 7. (Right)
100 KV Pulse Transformer
after encapsulation.

Table IV

Properties of A Polyester Potting Compound

A Insulation resistance (ohms) vs. temperature (as specified in I-B)

85°C	105°C	135°C	150°C
4.4 x 10^{10} ohms	3.6 x 10^{10} ohms	4 x 10^{8} ohms	Electrodes become loose in softened potting compound

A Thermal shock 105°C to -55°C (as specified in II-C)
4 samples failed in the 1st cycle.

A Heat distortion temperature 264 psi 90

B Shrinkage during cure (1%) 8.0

B Dissipation factor at Room Temperature

60 cps	0.0035
10^{3} cps	0.0028
10^{6} cps	0.012

COMMENTS

This table shows the results of tests on a typical polyester potting compound. It is interesting to note that even though base polyester was modified with a flexibilizing polyester the material failed in the thermal shock test in the first cycle. The high degree of shrinkage, to poor resistance to thermal shock, and generally low insulation resistance at elevated temperatures of polyester has limited our use of these materials as general purpose potting materials.

A	A mixture of flexible polyester	50 parts by wt.
	Rigid polyester	50 parts by wt.
B	Rigid polyester, as in A	

MOLDING CYCLES

Edited by **Louis Paggi**, *Consultant, E. I. du Pont de Nemours & Co., Inc.*

Color Blending

Louis Paggi

ONE OF THE PROBLEMS which often confronts the molder is that of obtaining a good blending of color when molding with plastic granules where pigment has been applied to the surface by dry blending. The problem can be eliminated by obtaining complete homogeneity of the molten plastic, but this is difficult to achieve except by such means as an extrusion-blending operation which generally is an additional processing step. However, it is often possible to obtain blending to a satisfactory degree within the injection molding machine by modification of the equipment plus effective control of the molding operation to make use of certain basic principles.

A Good Example

A good example of adequate color blending may be seen in any newspaper or magazine carrying reproductions of photographs. If the reproduced photograph is viewed through a magnifying glass it will be seen that it is composed of a great number of small isolated ink spots rather than one continuous film of pigment. To the unaided eye the individual spots are indistinguishable, therefore, the image appears to be continuous and unbroken. If the image were to be printed on a sheet of glass, depositing every other spot alternately, and in proper register, half on each side of the glass, the image when viewed against the proper background would again appear to be undivided. If the glass were not transparent, we would see only half of the spots and the picture would appear to be grainy. Following this principle, we find that the more opaque the substance the greater must be the percentage of pigment used and the better must be the blending in order to reproduce the same intensity and uniformity of color.

Even Coloring

In this molding problem, the objective is to obtain an even distribution of pigment so that the color will appear to be continuous to the naked eye. Therefore, the relatively isolated masses of pigment on the surfaces of the granules must be divided into fine particles and distributed throughout the plastic. Effective blending can be achieved only by sub-division of the cross-section of the melt stream as shown in the accompanying illustration. This can be accomplished in several ways, but the method chosen must be one which is practical and economical to use in existing equipment or by a slight modification of existing equipment.

Linear Flow

With the exception of machines having power-driven mixing screws, all molding machines operate with linear flow through the plastifying cylinder. This type of flow does not lend itself to the high degree of shearing necessary for good blending unless one or more restrictions are present in the melt stream within the cyiinder and/or nozzle. Allowing the melt to turn several angles on its way to the mold will not result in sufficient turbulence or shearing to improve blending to a noticeable degree. In order to obtain shearing, part of the mass of material must flow at a different rate than that of adjoining material. In the molding machine, this is accomplished by forcing a large cross-section of the coarse mixture through a considerably smaller and very short restriction. It is necessary, for practical reasons, to employ short, small diameter orifices rather than long ones, in order to combine the best blending with the least pressure loss. To reduce the pressure loss due to the restriction of a single slim orifice, several small orifices or a single thin annulus of considerable circumference can be used.

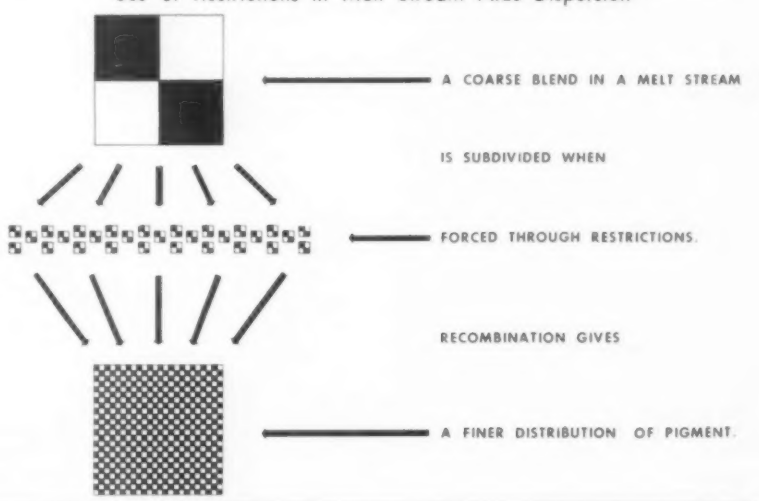
Color blending through an injection molding machine will involve the following steps:

Dry Blending

The object in dry blending is to disperse the pigment over as large a surface-to-volume ratio as possible. This means that a plastic granule having a rough surface is preferred over a smooth one since the former exposes more surface to contact with the pigment than the latter. For the same reason, fine granulation is preferred over coarse. This explains why the use of reground material having a high percentage of "fines" will result in better color blending than use of common cut granules of uniform size. Incorporating wetting agents such as certain waxes or oils in the dry blend will promote better adhesion of the pigment to the plastic granules and, therefore, more uniform blending in the final product. However, any wetting agent used must be compatible with the plastic formulation used. Thorough mixing of the dry-blend is of course necessary in order to eliminate "islands" of high pigment concentration in the blend.

Many molders prefer to use "color concentrates" rather than direct coating of the plastic granules with the pigment. A "color concentrate" will consist of plastic granules, in which has been incorporated a very high percentage of pigment. A concentrate of twenty to one indicates that the "color concentrate" carries 20 times

Use of Restrictions in Melt Stream Aids Dispersion


A COARSE BLEND IN A MELT STREAM
IS SUBDIVIDED WHEN
FORCED THROUGH RESTRICTIONS.
RECOMBINATION GIVES
A FINER DISTRIBUTION OF PIGMENT.

as much pigment as necessary. The blend of concentrate and uncolored plastic fed to the molding machine will, therefore, have a ratio of nineteen parts of uncolored material to one part of the concentrate.

The use of "color concentrates" in preference to straight pigments is considered by many to be more costly. The reverse is often true if we consider the following advantages derived from the use of concentrates.

1. The concentrate will not drift throughout the work area, therefore, the operation is cleaner.
2. Weighings will involve larger quantities and will, therefore, be more accurate.
3. The concentrate will remain more evenly distributed throughout the hopper of the machine and result in more uniform color dispersion.
4. Concentrates will not contaminate feed mechanisms and cylinders as will straight pigment resulting in more rapid purging of cylinders between different colors.

In addition to the relatively higher cost of color concentrates, certain combinations of material properties, equipment, and part design, may not yield sufficiently uniform color dispersion. When this occurs, the molder has the choice of reducing the ratio of color concentrate or of coloring by dry-blending.

Equipment Design

In the absence of mixing screws as part of the molding machine, the material can usually be satisfactorily blended by forcing it through one or a series of restrictions on the way to the mold. Since any form of restriction results in a pressure loss, care should be taken to locate restrictions in the forward section of the plastifying cylinder and in the nozzle where the material will be in a completely molten state. For the same reason of minimizing pressure loss, any form of restriction should also be as short as possible.

Restrictions in the plastifying cylinder can take the form of a thin annulus between the wall of the cylinder and the spreader or a series of small diameter holes connecting two larger ports within the cylinder. Any restriction within the cylinder and nozzle must be in the order of 0.040 inch wide or smaller in order to be effective. The smaller the size of the restriction the more effective will be the mixing. Any restriction in the melt stream should be designed with a view toward maintaining a streamlined flow. Sharp anglers in the melt stream may result in the formation of "dead spots" where the melt may be held up and degradation may occur.

The location within a plastifying cylinder where a restriction is most practical is the point where the flow begins to converge on its way to the nozzle. This section can be considerably reduced in area without seriously affecting pressure, provided the restriction is short in the direction of flow.

The next area of restriction can be at the entrance of the nozzle proper. This restriction may take the form of one or more drilled plates separated by spacer rings. The plates must be thick enough to support the pressure delivered by the cylinder in the event that unfused granules block some of the drilled holes. For the average installation where the plates are less than one inch in diameter, a thickness of 3/8" of steel has been found to be satisfactory for the plate located at the cylinder side of the nozzle. Other plates may be thinner, say 1/4", since these plates are not likely to be subjected to high differential loading due to plugging with unmelted granules. A practical diameter for the drilled holes is 1/32 inch. If the 1/32 inch holes result in excessive pressure losses the holes may be counter-bored or reamed on the mold side of the plates to within a few thousands of the cylinder side of the plate.

In a nozzle of this design the melt enters through a large passage, from which it is forced through a number of small holes in a drilled plate. The high velocity of the melt through the small holes causes a high degree of shearing which results in good color blending.

Design considerations for nozzles of this type are:

a. The smaller the size of the drilled holes in the plate the better the blending but the greater the pressure loss.
b. The greater the number of holes across the area of the plate the less will be the pressure loss, but the lower velocity of the melt will also result in less shear and poorer blending.
c. The longer the path of flow through any restriction, the greater the pressure loss.

A final restriction may be at the gate into the cavity. The smaller the cross-section of the gate the more effective the blending. Thin flat gates are more effective than gates of any other geometry having the same cross-sectional area. Of course, if the part can be filled with a very small gate, the round gate may be preferred but if the cavity requires a relatively large volume of material, the gate may be wide and thin rather than to increase its size in all directions and thus reduce the effect of blending due to shearing.

Molding Temperature

Thorough blending is dependent on the plastic being completely melted as well as on the development of a high degree of shearing of the melt. This means that the temperature of the cylinder should be high enough to insure complete melting of the plastic but low enough to insure a high degree of shearing at the restrictions designed for blending. ★ ★

Koppers Sponsors Toy Design Contest

Summer camps for handicapped children will benefit to the tune of $5,000 in the 1958 Design Competition for Plastic Toys sponsored by Koppers Company, Inc.

This amount will consist of five first-prizes of $1,000 to winning molders in each of five classifications. These winners will receive from Koppers a list of accredited summer camps for handicapped children in the United States. The camp selected by the molder will then be given a $1,000 grant by Koppers in the molder's name. In addition, there will be three honorable-mention awards made in each of the five categories.

This competition, which is designed to promote and upgrade the use and application of plastics in the toy field, is open to all molders, extruders, fabricators or proprietary manufacturers of polystyrene and polyethylene toys. All entries must consist substantially of a recognized type of polystyrene (regular, modified, or foam), or regular or rigid polyethylene.

Heading the list of a distinguished judging panel is Dr. Frances Horwich, the beloved Miss Frances of televisions' famous "Ding Dong School." Others on the panel are Dr. Jesse H. Day, editor of the S.P.E. JOURNAL and member of the Society of Plastic Engineers; and William M. Goldsmith, president of the American Society of Industrial Designers and professional designer for Design Research, Inc. of Chicago, Illinois.

Although this is the fourth annual plastic design competition, it is the first one designated for toys. The three preceding competitions were for plastic housewares. Hereafter, the Company will alternate toys and housewares annually.

Five Classifications

For award purposes, entries will be classified and awards made in five divisions:

Class I. Hobbycraft products. Items designed for use in hobbycraft.

Class II. Playtoys. Playtoys with a retail value of **more** than $5.

Class III. Playtoys. Playtoys with a retail value of **between** $1 and $5.

Class IV. Playtoys. Playtoys with a retail value of **less** than $1.

Class V. Infant items. Toy products designed for children too young to walk.

Entries should be shipped, mailed or delivered by midnight, April 13 to Administration Committee, Koppers Design Competition, 950 Koppers Building, Pittsburgh 19, Pa.

SPEAKING OF EXTRUSION

Edited by R. D. Sackett
Technical Service Associate
Monsanto Chemical Company
Springfield, Massachusetts

Extrusion Highlights of the 1958 ANTEC

Robert D. Sackett

TO SAY THAT THE 14th National Technical Conference was a success would probably be an understatement. The committee is to be congratulated as everything went off pretty much like clock work. If I were to name one thing that impressed me most, it would be "Acoustics". There was not a single session that I attended where there was any difficulty in hearing the speaker and that certainly was a pleasure.

There were 12 papers given in the extrusion sections and, of course, comments on extrusion crept into many other papers. The greatest single highlight of this conference, I am sure we will realize in years to come, was the meeting held by the Professional Activities Group on extrusion. This group provides us with a means of unified effort in accomplishing tasks of mutual interest. The committee, under the chairmanship of John Myers of Celanese, is just in the stage of setting up subcommittees and determining which project should be handled first. The ultimate success of this organization will be in direct relationship to the effort we of the extrusion industry are willing to expend. Many special talents will be required, so please make yourself available when asked to "volunteer" for sub-committee work.

Practical Papers

There were only two of the twelve papers that were strictly theoretical and I am sure that this met the approval of many. The interesting fact concerning this is that both the joint paper by Hulburt and Katz of American Cyanamid and Street of Welding Engineers, and the paper by Squires of du Pont came up with a so called "shape factor" for use in extruder screw design calculations. The two independent works had remarkable agreement.

Squires of du Pont delivered a very interesting paper that added certain refinements to the earlier well known du Pont theoretical extrusion studies.

Simplified Theory

The simplified extrusion theory has become quite widely used as a working tool, while the exact theory has been pretty much relegated to the extrusion researcher. The simplified extrusion theory is accurate to within about 6% for shallow screw (with channel depth to width ratios of 0.1 or less). Frequently, however, the simplified approach is applied to deeper screws with poor correlation. Growing interest in extraction screws, where deep flights, only partially full are desirable, pointed out the need for an improved method of estimating pumping capacity. Squires has presented an easy to use method whereby flight edge effects and screw channel curvature can be taken into consideration when calculating screw melt-pumping rates in either full or partially empty screw sections.

Depth to Width Ratio

Squires has shown, in graphical form, that the retarding action of the flight faces, on both the drag and pressure flow, increases as the screw channel becomes relatively deeper. It is shown that a screw having a channel depth to width ratio of 0.5 will convey fluid in drag flow with an efficiency of 73% as compared to the same screw with no flight edge effects. This paper also gives a curve for determining the shape factor when screws are run only partially full such as with extraction screws. In this respect it should be noted that the pumping capacity of the screw increases more than proportionately as this channel becomes fuller. This accounts for the fact that certain vented extruders operate better as speed is increased.

Squires goes on to show that the curvature of the flight is also important and presents data indicating that the curvature correction factor is greater than 1. Because of this the author suggests the diameter (D) to be used in the simplified approach should actually be the outside screw diameter rather than a mean diameter that has been suggested by others.

Melt Flow

The work of Street of Weldings Engineers and Hulburt of American Cyanamid descibed the flow of the plastic melt in the screw channel in a manner somewhat different from the method others have used in the past. It has been customary to explain the movement of plastic in the flight by assuming that a two parallel plate system existed where the barrel was one plate and the screw the other. This technique neglected the end effects (the effect of the flights). Street demonstrates by means of a graphical analysis that the screw flight contributes a flow component. In other words the screw flight acts as a snow plow. Obviously the material must tend to adhere to the barrel if the flight is to push the plastic. Hulburt's work explained (as did Squires of du Pont) from a theoretical standpoint that the flights did have a definite effect on the melt flow in the channel and a graph is shown giving the Shape Factor for various depth to width ratios.

Friction Heating

Maddock of Bakelite emphasized that the relative proportions of energy put into the plastic by frictional heat from the drive motor and by conducted heat from the cylinder heaters will depend primarily on three factors; screw design, screw speed, and the melt viscosity of the resin. Although it might appear desirable from an economic standpoint to obtain this energy from conducted heat, it has been shown that product quality is a function of mechanical energy input. Contrary to general belief the amount of conducted heat added will only be sufficient to make up the difference between the mechanical heat developed and the total heat input to the system. Any increase in shear rate or resin viscosity, therefore, will raise the ratio of mechanical to conducted heat input. It was stated by Maddock, that both theory and practice indicate that frictional heat and stock temperature must rise with increasing screw speed. This can be controlled to some extent by screw design and Maddock feels that it should be practicable to operate extruders at considerably

higher screw speeds than those presently employed.

PVC Dry Blend

Hankey and Sackett of Monsanto in their paper on PVC Dry Blend Extrusion made several points of interest. It was pointed out that dry blending conditions, primarily end-temperature, had a significant effect on extrusion rate and porosity due to entrapped air. Lower end temperatures resulted in higher extrusion rates, lower porosity, but poorer surface appearance. Longer screws (20-1) were shown to improve output as much as 35%. The importance of shallow flighted metering screws was demonstrated to result in higher outputs of good quality product. Hankey went on to tell, that because of the direct relation between quality and die resistance the quality of PVC dry blends can be improved by "valved extrusion techniques". This can be accompanied by increased outputs when higher screw speeds are used. The authors felt, that although porosity could be reduced by proper blending conditions and longer screws, the vented extruder (or equipment of this type) would become of increasing importance in the PVC dry blend field. Although the work was done in conjunction with wire coating, the results are applicable to any phase of PVC dry blend extrusion.

Pipe Extrusion

Morris of Spencer discussed some experimental results relating to the effect of extrusion conditions on burst strength of pipe. He found best results with O.D. draw rates of 25 to 30%. Stock temperature affected the surface appearance primarily.

Croley and Doyle from Phillips described the process for making pipe from linear polyethylene. They recommended the use of a jacketed cooling fixture for size control. Very excellent gloss is obtainable by this method on both the I.D. and O.D. Croley discusses several methods of maintaining air pressure (inside the pipe) including a new cut-off technique presently under development. A very simple butt welding technique is also described. In this method the two surfaces are heated by an electrical hot plate and then pressed together in a simple fixture. An actual installation where over 4,000 of these welds were used is reported as being entirely satisfactory.

Monofilaments

A Bakelite paper by Groel and Versteeg covers the monofilament process using the newer low-pressure polyethylene resins. The most promising feature of low pressure polyethylene is its high tensile strength, placing this material among some of the strongest fibers now on the market. There appeared to be no special extrusion techniques required for this product. The paper describes some of the drawdown techniques.

Sheet Extrusion

Farrow of Koppers and Griesser, Griff and Tomfohrde of Bakelite gave separate papers covering the flat sheet extrusion of high-density polyethylene. Regular styrene sheet equipment including similar dies and take-off equipment are suitable. Both speakers mentioned the importance of preventing sagging of the sheet as it comes from the die. Farrow suggested keeping the rolls close to the die, and the Bakelite group proposed feeding between the top two polishing rolls and then down around the bottom roller of a three roll stack. The Bakelite paper further suggested either lower compound temperatures and/or lower cooling roll temperature if "roll plating" becomes a problem. "Roll plating" is the plating out of low-molecular weight polyethylene on the polishing rolls and thus preventing good polishing. As Farrow pointed out, however, too cold cooling rolls will result in severe shrinkage which will also have poor appearance. Both papers discuss some of the special techniques used in vacuum forming this increasingly popular plastic.

Fluorocarbon Extrusion

Mallouk and Thompson of du Pont delivered a paper on Teflon 100X—a new melt extrudable Fluorocarbon resin. Conventional extruders with Z-nickel liners and screws will satisfactorily handle this new resin. Typical barrel and die heats range from 500°F to 740°F. Mallouk and Thompson state that thin wall wire coatings can be applied by the "tubing-on" technique—they go on to mention that thick wall coatings (over ¼") appear feasible but will require further development of the "forming box" technique. The "forming box" technique uses long landed dies and then immediately into a water jacketed cooling chamber where it is held against the walls by light air pressure. This same technique is used in the extrusion of heavy wall tubing and rod stock. Bottles may also be blown from this same resin. It is anticipated that the improved ease by which this material can be extruded, including reworking of the scrap, should result in expanded use of this true Perfluorocarbon polymer.

Nylon Processing

Allied Chemicals Paper by O'Toole, Tinger and vonToerne discuss the importance of recognizing the effect of environmental and processing conditions on the properties of nylon 6. The paper discusses the effect of absorbed moisture, water bath temperature, and post extrusion annealing on the strength of extruded tubing. Some of the techniques employed in extruding nylon 6 tubing are covered in order that the maximum potential properties of this relatively new extrusion material may be fully realized.

Film Properties

The paper by Haine and Robinson of Bakelite covers the extrusion variables and the effect that these variables have on the quality of flat polyethylene film with controlled properties. The authors point out that although film extrusion from a mechanical standpoint appears on the surface to be a simple process, it is a fairly complex one from a rheological standpoint. Variables discussed are compound temperature, film speed, draw distance and water bath temperature. It is acknowledged that other variables are of importance but it is pointed out that through the proper control of the above mentioned variables controlled property film at economically feasible production rates can be produced.

Thickness Control

Doering of Industrial Nucleonics discussed several different beta gauge set-ups used in conjunction with extrusion operations. He stated that since most characteristics of films are dependent to some degree on output rate beta gauge control can result in higher quality. Real justification of the gauge is generally made on the basis of improved yield. Doering quoted a comment from "Paper Trade Journal" where one polyethylene laminator calculated that the equipment had paid for itself in six months in direct cost reduction. Improvements are continually being made in equipment for the analysis of machine performance. Mr. Doering predicts that this method of product quality control will be used to a considerably greater extent as a means of standardizing operating conditions. ★★

Bachner Award for Plastics Uses Announced

Outstanding contributions to the practical applications of plastics will be honored this year with the inauguration of the Bachner Award sponsored by the Chicago Molded Products Corporation as a testimonial to the work of the five Bachner brothers who founded the company 39 years ago and to the many others who have contributed to the growth of the plastics industry.

The award will consist of a plaque by well-known industrial designer, Jean Reinecke, and $1,000.

Information and entry applications may be obtained through William T. Cruse, The Society of the Plastics Industry, 250 Park Avenue, New York 17, New York.

Epoxy Resins . . . .

(Continued from page 52)

cured with a bifunctional aromatic amine; this combination was selected because it had greater resistance to thermal shock than any of the systems tested. Another favorable property of the epoxy-silica-amine system was a high insulation resistance at elevated temperatures. A low viscosity for good penetration of the coils insured a void-free casting.

Figure 8 shows several cast toroidal units. The toroids were wrapped in mylar film to prevent penetration of the casting resin into the windings and the ferrite core. An epoxy laminate was used as the mounting bracket. The mold assembly is also shown.

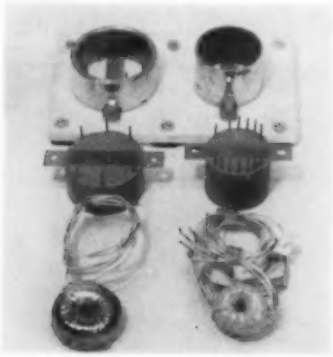


Figure 8. Toroid Packaging. (left) Single (right) Double

IV. Conclusions

As the excellent electrical and thermal properties of epoxy resin systems become more widely known, the uses of these versatile materials increase in the electrical insulating field.

By coordinating the design and the resin system, successful applications will result. We have shown some tests that are useful in evaluating epoxy resin systems and discussed some design considerations which help utilize these resin systems more successfully.

Identification of Resins and Hardeners Mentioned.

Resin	Common Chemical Name
Epoxy A	Unmodified low viscosity epoxy resins.
Epoxy B	Epoxy equivalent of .52/100 gm.
Epoxy C	Unmodified medium viscosity epoxy resin; epoxy equivalent of .46/100 gm.
Epoxy D	Proprietary casting resin-phthalic anhydride hardener.
Epoxy E	Proprietary high temperature casting resin.
Epoxy F	Proprietary epoxy casting resin room temperature setting.

Hardeners	Common Chemical Name
Secondary Amine	Piperidine.
Amine Salt	2, 4, 6-tri (dimethyl aminomethyl) Phenol-tri-2-ethylhexoate.
Amine Comples of Boron Trifluoride	Monoethanolamine complex of boron trifluoride.
Solid Aromatic Amine A	Methylene Dianiline.
Low Melting Anhydride	Hexahydro Phthalic Anhydride.
Solid Aromatic Sulfone DADPS	Diamino Diphenyl Sulfone.
Liquid Aromatic Amine A Liquid Aromatic Amine B Liquid Aromatic Amine C Liquid Aromatic Amine D	Proprietary aromatic amines normally liquid at room temperature.

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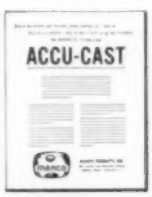

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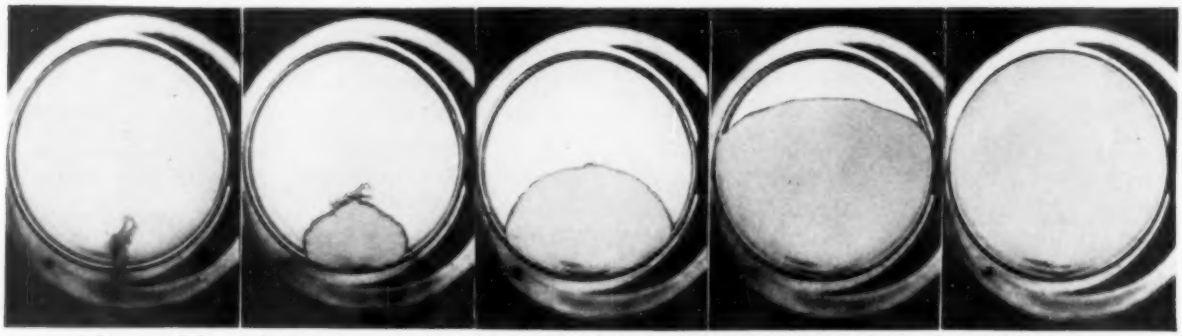
MARCH
1958

Plastiatrics

DOW'S CLINICAL APPROACH TO HEALTHY PLASTICS APPLICATION

BEHAVIOR OF POLYETHYLENE INSIDE MOLD CAVITY STUDIED

GLASS WINDOW IN MOLD ALLOWS CLOSE STUDY OF FLOW BEHAVIOR PATTERNS



Sequence of photographs above shows polyethylene of melt index 2 jetting into mold cavity at left and finally filling the mold at right.

A careful study of molten polyethylene inside the mold cavity has provided important new information on its behavior patterns. For example, as the material enters the mold and starts to cool, crystallization begins at once (see chart below). One result of this crystallization is the formation of a weak front which, due to pressure from incoming material, breaks up and tends to re-form inside the mold. The motion pictures taken through the glass window (see photos above) show several other interesting features:

1. Polyethylene has a tendency to jet when entering into the mold cavity.

2. The finish of the molded part may show blemishes where the material in the jet and the molten front meet and do not weld properly.

3. As the molten material flows into the mold, curvature of the front does not reverse, indicating that polyethylene does not wet the glass mold walls.

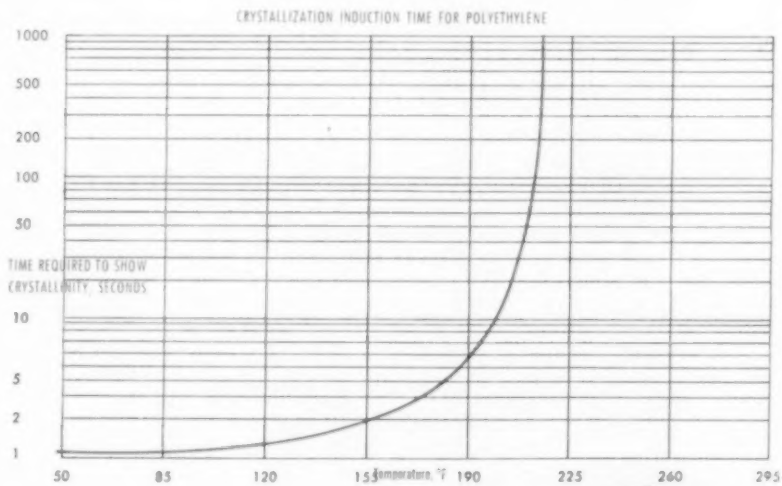
4. When polyethylene is forced against the mold wall and becomes solid, it does not stop flowing but is scraped along the mold walls in the direction of flow.

5. Polyethylene has a tendency to pack in the mold under a wide range of operating conditions.

Dow Technical Service Engineers have made a thorough study of the performance characteristics of polyethylene in injection molding. This is a part of a continuing series of Plastiatrics studies covering every phase of plastics formulation, design, molding and finishing. For your copy of "Injection Molding Polyethylene", write THE DOW CHEMICAL COMPANY, Midland, Michigan, Plastics Sales Department 1519F.

DOW POLYETHYLENES
INJECTION MOLDING GRADES

LOW DENSITY	MELT INDEX	
700 M	7.0	
900 M	20	
410 M	1.5	
610 M	5	
710 M	12	
910 M	28	
INTERMEDIATE DENSITY		
770 M	0	
771 M	8	—slip characteristics
990 M	20	
991 M	20	—slip characteristics
1000 M	35	



YOU CAN DEPEND ON DOW

Action— By Your National Organization

"The objects of the Society shall be to promote in all lawful ways the Arts, Sciences, and Engineering Practices and Standards connected with the utilization of plastics."

ANTEC HIGHLIGHTS

So much National Action was going on at our Fourteenth ANTEC in Detroit, that only the highlights can be reported here:

Your **1958 ANTEC** itself was from any angle the biggest and best in SPE's history. For example, compared with past conference records:

Registration:	over 2,500; up 25%
Number of Papers:	99; up 39%
Number of Sessions:	26; up 53%
Days of Duration:	3½; up 40%

Quality-wise the outstanding technical program covered the extensive plastics field like a blanket, and the conference operated as smoothly as a high-compression Detroit-built engine.

Hats off to General Chairman, Carl H. Whitlock and his fast-cracking, hard-working Detroit Section team!

A Plastics Institute, for years the cherished dream of Past President Jerome L. Formo and his Institute Committee, moved a long step toward reality at National Council meeting. Council resolved unanimously to join with SPI, MCA or other interested organizations in sponsoring the Institute. In its formative stages, it is proposed that each sponsoring Society will appoint three members to a temporary Board of Directors. Each sponsoring Society will underwrite the organizational effort to a maximum of $10,000 each; this sum to be returned to the underwriter within three years after establishment of the Institute.

Revisions to By-Laws B-13 and B-16 by letter ballot were announced at National Council Meeting. B-13 was revised by eliminating the last sentence which states that Foreign Sections shall be billed for the SPE JOURNAL on the same basis as members for dues. The B-16 revision increases the period during which full initiation fees of new members affiliated with a new section are remitted to that Section from the first twelve months to the first twenty four months following recognition by the National Council of a new section. After that, one-fourth instead of one-half of the initiation fees shall be remitted to each Section.

Dr. Jesse H. Day has been promoted to chairman of the Chemistry Department at Ohio University, effective February first according to the announcement of John Baker, President. When the Editorial offices of the Journal are consolidated in the Society's National Office in Greenwich this year, Dr. Day will be elevated to Editor Emeritus of the SPE JOURNAL, and Charles E. Rhine will take over as Editor. As Editor Emeritus, Dr. Day will continue as an active member of the SPE JOURNAL Staff, and his long and rich experience in developing the JOURNAL will be available to Mr. Rhine.

Professional Activity Groups came into full bloom at ANTEC. In fourteen separate meetings of groups and chairmen, attendance averaged over 20 and hit a high of 65 in one group. The vigor and enthusiasm displayed indicate that these groups will soon become a vital part of SPE's National structure and service.

SPE Membership has almost reached its 1958 goal of 6,400, according to the report to Council of G. Palmer Humphrey, National Membership Chairman.

Returns from the Membership Survey to date have been disappointing, according to the report to Council of Byron Nelson, Chairman of the Ad Hoc Membership Survey Committee. As of January 22, 1958, only 1,694 returns were received in the National Office—about 29% of the membership. To get maximum value from this survey, returns must approach 100%. So, if you haven't done so already, *please fill out and return your form immediately.* If you've mislaid your forms, duplicates will be sent you on request to the National Office.

The Publications Committee report to Council by Chairman C. D. Kacalieff, reflected intense activity in this area. Charles E. Rhine, who will become Editor of the SPE JOURNAL, and Publications Editor when the Editorial Offices are consolidated in the National Office later this year, was introduced to Council. Mr. Rhine was formerly Managing Editor, Plastics World, and brings to the SPE a broad knowledge of plastics and the plastics industry and thorough experience in all phases of magazine editing, printing, and publishing. The illustration heading this section gives news of the present SPE JOURNAL Editor, Dr. Jesse H. Day. In addition, plans for more thorough National advertising sales coverage and a new format for the SPE JOURNAL were discussed.

The Meetings Committee report to Council by its Chairman, Frank A. Martin, was featured by unanimous adoption by acclamation of the "Manual of Procedures—ANTEC, NATEC, and RETEC." All agreed that this was a monumental contribution to the progress of the Society. It explains in part the award of the first President's cup to Mr. Martin. *(Photo page 60).*

Frank A. Martin
For Distinguished Service—
The President's Cup

Frank A. Martin, Chairman of SPE National Meetings Committee, was awarded the first "President's Cup" at the Fourteenth ANTEC Banquet by Peter W. Simmons, 1957 National President. The cup is awarded to the SPE member, other than National Officers and members of the National Executive Committee, who, in the opinion of the Executive Committee, has made the outstanding contribution to SPE during the preceding year.

The 1963 ANTEC was awarded to the Southern California Section. It will be held in the Ambassador Hotel, Los Angeles.

Six RETECs were approved for 1958 and one for 1959, showing the growth of this successful type of meeting:

1. April 18, 1958—"New Development in Injection Molding Techniques"—Chicago
2. September 12, 1958—"Plastics in Automotive Applications"—Detroit
3. October 1, 1958,—"Plastics in Packaging"—Hartford, Connecticut
4. October 21, 1958—"Epoxies"—Upper Midwest Section—Minneapolis
5. October 24, 1958 — "Plastics and Electronics" — Golden Gate Section—San Francisco, California
6. November 13, 1958—"Plastics in Building and Construction"—Los Angeles, California
7. May 7, 1959—"Plastics and the Metal Industry"—Pittsburgh

The Central New York Section was approved by Council as SPE's 38th Section, on the petition of James R. Lampman, Temporary Section President. This is the second section to receive its charter during the 1957-1958 year, the other being the Rocky Mountain Section.

Company Registrations at SPE'S FOURTEENTH ANTEC

Admiral Corporation, Molded Products Division
P.O. Box 338, West Chicago, Ill.

Advance Solvents & Chemical Div., Carlisle Chemical Works, Inc.
500 Jersey Avenue, New Brunswick, N. J.

National Aniline Division, Allied Chemical & Dye Corp.
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Bakelite Company
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Industrial Nucleonics Corp.
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Koppers Company, Inc.
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Kordite Company
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Lincoln Plastics Corp.
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75 Droyers Street, Jersey City 3, N. J.

Modern Plastic Machinery Corp.
15 Union St., Lodi, N. J.

Mold-A-Matic, Inc.
1731 E. 11 Mile Road, Madison Heights, Michigan

Monsanto Chemical Company
Springfield, Mass.

The Morningstar Corp.
156 Sixth Street, Cambridge 42, Mass.

Moslo Machinery Co.
2443 Prospect Avenue, Cleveland, Ohio

H. Muehlstein & Co., Inc.
4237 West 42nd Place, Chicago, Illinois

Mycalex Corp. of America
125 Clifton Blvd., Clifton, N. J.

National Rubber Machinery Co.
47 W. Exchange St., Akron 8, Ohio

National Tool & Mfg. Co.
100 North 12th Street, Kenilworth, N. J.

Naugatuck Chemical Division, U.S. Rubber Company
Naugatuck, Conn.

Newark Die Company
24 Scott Street, Newark 2, N. J.

Nixon Nitration Works
Nixon, N. J.

(Please turn to page 71)

NEWS of the industry

New Egan Plant

Completion of a $165,000 addition to the Frank W. Egan & Company plant in Adamsville Rd., Somerville (N.J.), was announced today by Edward F. Egan, President.

The firm, which manufacturers machinery for the paper converting and plastics processing industries, has doubled the size of its plant since 1955. The 16,000 square feet of floor space provided by the new wing will be used to increase manufacturing, office and laboratory facilities.

Egan said the new laboratory will be devoted to testing and research in both the plastics extrusions and paper converting fields. The plastics section, already in operation, is equipped with a 2½" extruder and a complete line of auxiliary equipment.

Office Moves

It has just been announced by Boston Division Sales Manager, Edward C. Richardson, of the U. S. Industrial Chemicals Co., Division of National Distillers and Chemical Corporation, that the Boston office is being moved. The new U.S.I. address is 150 Causeway Street, Boston 14, Massachusetts.

Isochem Resins

Isochem Corporation takes pleasure in announcing the formation of a new affiliate, the Isochem Resins Corporation, conceived specifically to serve industry with specialized formulations in the epoxy, polyester and allied resins fields.

The specific function of Isochem Resins Corporation will be to make formulated compounds available to mitigate diverse technical problems in those industries which utilize adhesives, coatings, impregnants, moulding, tooling, patching and casting compounds, potting formulations, and a variety of similar products. In addition to its complete product line Isochem Resins Corporation will also offer competent on-the-spot technical service.

New Vacuum-Former

Robinson, Lewis & Rubin, Inc., of 132 Lafayette Street, New York, 13 N. Y., has announced its entry into the field of vacuum forming, low pressure forming and fabrication for the needs of industry.

Daniel Lewis, as President, was formerly Sales Manager of Durable Formed Products and Vice President of Tiger Plastics Corporation.

Associated with Mr. Lewis, are Sol M. Robinson, President of Robinson Plastics Corp. Irvin I. Rubin, Vice President of Robinson Plastics Corp. and Irwin Robinson, Treasurer of Robinson Plastics Corp.

Techni-Plastics Formed

Techni-Plastics, Inc., with complete manufacturing facilities in the specialization of thermoplastic forming and fabricating, has been formed.

The following members have been elected to serve on the Board of Directors:

Vito A. Tanzi—President & Chairman of the Board; Walter R. Speck—Vice President; Robert A. Gerardi—Treasurer & General Manager; Gilbert G. D'Andrea—Secretary.

Their location is 4 Yennicock Ave., Port Washington, Long Island, N. Y.

Plastic Factors, Inc.

Plastic Factors, Inc., announces a move from San Carlos, California, to expanded facilities in a 9,000 sq. ft. modern production plant at 926 Broadway, Redwood City, effective November 1.

The Corporation's Peninsula installation quadruples previous working space. The management predicts additional modern equipment and expert personnel will surpass last year's record production of over 500 different plastic items made for business and industry.

Mr. Frost, president of the company, is Vice President, Golden Gate Chapter, National Society of Plastic Engineers and resides at 8 Alameda De Las Pulgas, Redwood City, California.

Creep Tester

As many as six plastics specimens can be tested simultaneously in a Multiple Creep Tester developed by the Tinius Olsen Testing Machine Company.

Standard plastics specimens can be tested for indefinite periods of time under accurately controlled conditions of tension at temperatures up to 500°F. Load is applied individually to the specimens by means of dead weights. An insulated clear glass pane in the removable front panel of the unit permits visual inspection of the specimens at all times.

Additional information about the Olsen Multiple Creep Tester is available upon request to Tinius Olsen Testing Machine Company, 7416 Easton Road, Willow Grove, Pa.

Flambeau Plastics

Flambeau Plastics Corp., Baraboo, Wis. has started construction of a new plant and office building which, when completed, is expected to facilitate greatly the production of its products.

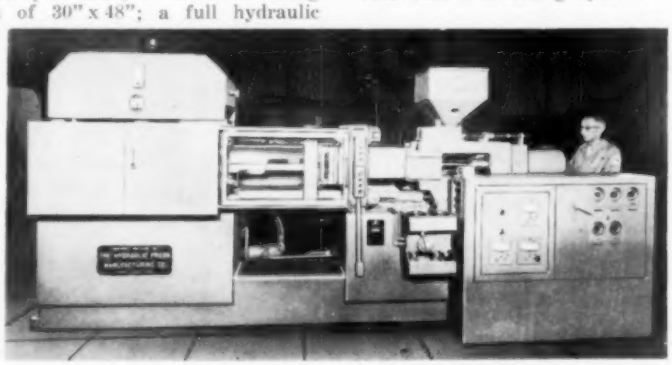
The new building is located on a 7⅓ acre tract within the city limits of Baraboo, Wisconsin. The initial construction will cover 31,000 square feet. The facilities to be housed include office space, manufacturing area, assembly and finishing areas, warehouse space, and the tooling division. The company expects to occupy the new premises by May 1, 1958.

HPM Announces New Injection Machine

The Hydraulic Press Mfg. Co., A Division of Koehring Co., Mount Gilead, Ohio, announces a new addition to its plastics injection molding machine line—a 32/42 ounce machine, claimed by H-P-M to be the fastest machine of its size on the market today.

This 650 ton unit, with a total of 107½ horsepower, features an extremely high injection rate of 2510 cubic inches of material per minute; exceptionally fast cycling of over 300 cycles per hour; a mold mounting area of 30" x 48"; a full hydraulic clamp with 30" stroke and 50" daylight. Clamp controls are centralized. Easily adjusted limit switches provide variable stroke, daylight, slow close for die contact, slow breakaway and injection stroke. A unique hydraulic device assures shockless operation.

Independent clamp and injection circuits allow simultaneous traversing of both clamp and injection rams. This feature eliminates dead time inherent in machines using a single circuit with a diverting system.



AROUND THE WORLD

★

UNITED STATES
A.S.T.M. BULLETIN
December, 1957

Abstracter: Walter A. Gammel, Sr.

Electrical Insulating Materials

ASTM Committee D-9 will ballot on new tentative specifications which include: a method for dissipation factor and dielectric constant of polyethylene, and a specification for polyester-glass general-purpose laminates.

Approved for submission to Editorial Board of the Committee were included a method for measuring corona resistance of insulating materials, and methods for thermal stability of varnished fabric employing curved electrodes with one test based on application of proof voltage and the other on dielectric breakdown.

★

MATERIALS IN DESIGN ENGINEERING
December, 1957

Abstracter: Leonard Buchoff

Rubber Phenolic Moldings — *E. J. Thomas*

Rubber phenolic molding compounds are blends of phenol formaldehyde resins and nitrile rubber filled with woodflour, asbestos, cotton flock or fabric.

A substantial portion of the properties common to phenolics such as good dielectric properties, relatively high heat distortion temperatures and attractive as-molded finishes is retained with the additional benefit of resilience.

This endows the material with resistance to abuse and ability to accommodate large inserts. The drop bull test is described and said to be a more accurate rating for impact resistance than the Izod test.

Designing for Injection Molded Plastics—*John R. Kent*

This article gives properties of the thermoplastics and design considerations important in injection molding. Acrylics are noted for their optical properties and resistance to weathering; cellulosics for their toughness, coloribility and ease of molding; chlorotrifluoroethylene for its good chemical and heat resistance and dielectric properties; nylon for its toughness and heat resistance; polyethylene for its toughness, resiliency and ease of molding; PVC for its resistance to petroleum oils and wide range of flexibilities; styrene for its moldability, dimensional stability and dielectric properties.

Design factors of draft, fillets, wall thickness, ribs, undercuts, holes, threads and inserts are discussed. The importance of welding in the mold on surface and strength is mentioned.

Two useful tables are given, describing the thermoplastics, one on comparative costs, the other on general properties.

Finishes for Wood—*Albert J. Kirsh*

The properties, application techniques, and cost of the various types of clear opaque and laminated finishes for wood are presented. Preparation of the wood surface is well described. Varnishes have good hardness and toughness combined with good resistance to heat, water, acids, alkalis and alcohol. The fast drying quality of lacquers make it well adapted to high production. The main disadvantages are the shrinkage qualities and need for multiple layers.

Low bake finishes usually consist of a combination of alkyd and urea formaldehyde resins. The finishes have the toughness and mar resistance of lacquers and better chemical resistance. In addition they are unaffected by lighted cigarettes and matches.

Polyester finishes have excellent appearance with better gloss and clarity than the average lacquer. It has excellent resistance to burning, hot water, chemicals, abrasion, cold checking and aging.

Exceptionally hard wear and heat resistant finishes are provided by melamine resin laminates bonded to wood surfaces. They also possess excellent color stability and appearance. Clear laminate finishes provide equal surface characteristics of the high pressure melamine laminates. They consist of an overlay paper impregnated with surfacing resin which can be laminated directly to wood surfaces at low pressures.

New developments of epoxy and urethane coatings, polyester finished hardboards and vinyl films are mentioned.

★

RUBBER AGE
November, 1957

Abstracter: James P. Harrington

A Uni-Rotor Mixer for Rubber and Plastics—*W. F. Watson and D. Wilson*

This mixer imparts both lateral and downward motion to a material by means of a single vertical rotor which is concentric in a chamber. This type of design results in an even torque during mixing and eliminates the escape of material or possible contamination at the shaft sealing glands found with twin-rotor mixers. The authors report excellent results compounding either elastomers or thermoplastics with a laboratory size uni-rotor mixer (2 to 50 gms capacity).

★

FRANCE
INDUSTRIE DES PLASTIQUES MODERNES
December, 1957

Abstracter: Hans Mayer

Agriculture Could be Transformed by Plastics—*Jules Soyeur.*

With the availability of plastic materials the first question regarding agricultural applications was the question of replacement of other materials formerly used, namely glass. In this respect methacrylates have been selected for use in hot houses and hot beds. Their employ instead of glass is a question of comparative costs only.

The availability of film of a polyvinyl or polyethylene base has opened the way for new techniques which have been widely different under different climatic conditions. Protecting the plants against excessive moisture, cold weather, and other outside in-

fluences, retarding or destroying the young crops, has made it possible to bring crops early to market, minimize losses, even raise two consecutive crops during one season where this had been formerly impossible. It is possible that an intelligent employ of these techniques will permit a great extension of production of agricultural products in countries dependent on import of these products now.

★

GERMANY
KUNSTSTOFFE
December, 1957
Abstracter: Anne Schwend

Properties of PVC Paste Resins—*Eng. Drahomir Rysavy*

This release from the Research Institute for Macromolecular Chemistry in Czechoslovakia deals with the resistance of PVC against solvation through plasticizers and stipulates a number of relative values differentiating the individual types of PVC. As a result of data obtained it is held that the extent of the specific surface of powdery PVC is the decisive factor for the speed of plasticizer solvation (as long as the K-value of the polymer remains within 65-80). Not only the external surface of the particle but also all internal surfaces offering easy access for plasticizers have to be taken into account. The degree of polymerization is only of secondary importance in this respect. The reactions of various types of PVC and their suitability for the production of pastes are investigated. Further, the influence of different drying temperatures on the properties of paste forming PVC, which is produced by drying the PVC latex with a spray drier, is laid down in a chart.

International Standardization of Plastics

Brief report on recommendations, draft proposals and current work down by the 7th convention of ISO Technical Committee 61 held in Switzerland in July 57.

Branding Devices for the Cable and Plastics Industry

A survey on means available on the European market to brand plastics covered cables, tubes, ribbons, profiles and other plastic items either by stamping or dyeing the surfaces, sometimes also marking meters, for better distinguishing the different types.

Effects of Incomplete Cross-Linking on the Physical and Chemical Properties of Unsaturated Polyester Resins — *Josef Fritz*

Two types of incomplete cross-linking are distinguished: 1. Temporarily incomplete cross-linking which has not undergone the maximum time of reaction and thus not reached the final stage of possible cross-linking. It may be remedied by an after-cure and heating to 110°C. for 2-3 hours. 2. Permanently incomplete cross-linking in which no after-cure at room temperature or multihour heating to elevated temperatures can induce a resumption of the interrupted reaction. Charts compare mechanical and chemical properties of fully cross-linked and incompletely cross-linked specimen. Factors promoting or inhibiting cross-linking are discussed.

Internal Stresses in PVC Cable Insulation—*Dr. F. O. Glander*

It has been known for some time that maximum strength in plasticized PVC can only be obtained by adequate gelation of the compound at processing temperatures changing with the type of plasticizer and its concentration. Low forming temperatures, too, impede the plastic flow of interlaced threadlike molecules and thus cause internal stresses in the product. Simple laboratory rolling tests demonstrated the order of influence on different mechanical properties of plasticized PVC through choice of gelation and forming temperatures. Shrinkage phenomenae upon sheathing of metallic conductors are especially discussed. The design of a suitable extruder nozzle is discussed.

The Condensation of Melamine with Formaldehyde at Controlled pH-Values—*Dr. Horst Michaud*

Not only basic materials of uniform composition but also continuous supervision of the reaction as far as the pH-value and the degree of condensation are concerned were found to be the key to steadily good products. Since basic materials do not represent chemically pure but rather technical products which may always contain small amounts of impurities which slightly disturb the uniform proceeding of reaction from batch to batch, the condensation process cannot be determined from the original pH-value of formalin and the reaction temperature alone. Conducted tests reveal that substances which strongly accelerate condensation reaction may be used as latent hardeners if they are added to the resin subsequently; upon final processing of melamine resins they modify the formaldehyde, which was separated at elevated temperatures, into formic acid and thru reduction of the pH-value augment the hardening speed.

Molding of Amino Plastics — *Jan Brzezinski and Z. Wirpsza*

This release from the Plastics Institute of Warszawa is a survey on the molding properties of amino plastics in order to get acquainted with processing possibilities. Comparative tests of urea molding compounds and melamine resins showed that

1. The temperature range for molding melamine is almost double that for urea resins. Exigencies as to constancy of mold temperatures are hence lower for melamine resins. However, to avoid stresses especially when wall thicknesses vary, temperature distribution on the mold surfaces should be as uniform as possible.
2. The curing speed of urea resins at comparable temperatures is bigger within 143 to 160°C. and below 143°C. lower than that of melamine resins. Increasing the molding temperature of melamine to appr. 170°C. shows curing speeds which approach those of urea resins at 160°C.
3. The flow properties of both resins decrease rapidly at increasing temperatures. Higher molding temperatures and thus shorter molding cycles are restricted hereby.

By plotting molding time and plate thickness for each individual molding temperature into a coordinate system, one gets a good impression of the moldability of urea and melamine resins.

The Kinetics of Curing Epoxyde Resins—*Dr. G. Kannebley*

Model substances of cyclo hexanol as low melting water-free secondary alcohols and low molecular technical resins as well as phenyl and isobutyl glycidyl ether as epoxyde components are used to observe the reaction speed constants and pertinent activation energies of the individual curing steps which are more distinguishable when curing with polycarbon acid anhydrides rather than with amines or polyamines. Tests aimed at stipulating minimum temperatures for curing and permitting predictions on the reaction of a resin to which a certain curing agent was added. Results are laid down in charts.

★

DER PLASTVERARBEITER
November, 1957
Abstracter: Leo Fischer

Insulation of Factories with In Place Foams—*H. Baumann*

Large factories especially those built of sheet metal in hangar style can be insulated for resistance to heat and cold. A phenol formaldehyde foam installation is described here.

Burlap cloth was attached to the beams and stretched tight. Slats are attached across the burlap to reinforce the foam and be a thickness guide. A second layer of burlap sheets is attached to the slats. The hollow space between the burlap is then filled with foam. The weight is 8 to 10 Kg per cu.m. The foam is then covered with a white brush coating of a nonflammable resin.

Multisided Vacuum Forming by Means of "Negative-Stretching" — *Alfred Riemenschneider*

In order to overcome the problem of uneven wall thickness in deep draw vacuum forming, a modified technique is described. Although a pneumatic forming method is not new, an improved technique for some products is that of a plunger and vacuum together. The plunger is 30% smaller all around in all dimensions than the mold cavity and is rounded at the bottom. It is slowly pressed into the heated sheet and into the mold thus stretching the sheet. Then the vacuum is applied for the final stretch. The piece is almost uniform in thickness throughout. Vacuum can be applied at the start if folds are formed by the plunger. This technique has great possibilities in improved and deeper vacuum forming according to the author.

Sheet Metal Plus Synthetics Equals Skinplate—*Dr. H. Kalpers*

Coating of metal with other metals is an old industry. The author discusses the subject of coating metals with synthetics. Advantages are resistance to chemicals, and superiority to all metals in appearance and decorative effects PVC is most widely used, not only because of the inseperable bonds and the general excellent qualities of PVC, but because skin plate with PVC can be fabricated and worked like uncoated metal.

Tests are given as to chemical resistance involving chemical exposures of 7 days, 17 days and fume exposures of 3½ years. The only change indicated in the 3½ year exposure was one of color. Results are also given for a 500 hr weatherometer test where no change took place. 1000 hrs. at 100% humidity showed no change except in gloss. Of special interest is the resistance of skin plate to a 600 hr. oven test. For applications to walls a contact adhesive is used, either in liquid form for brushing, or paste for troweling.

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GREAT BRITAIN

RUBBER AND PLASTICS AGE

September, 1957

Abstracter: Walter A. Gammel, Sr.

Self-Reinforced Elastomers (Butadiene Copolymers)—*E. E. Gale, H. A. Pfisterer, and E. B. Storey*

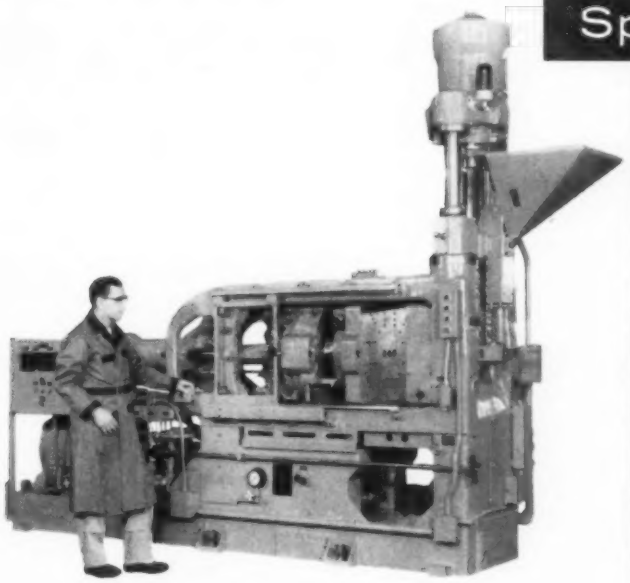
Rubbers and plastics can best be distinguished by the properties of the materials after vulcanization. The Customs Co-op Council defines rubber "as an unsaturated substance which can be irreversibly transformed into a non-thermoplastic substance by vulcanization with sulphur."

High styrene copolymers used for floor tile and soles of shoes are produced by copolymerizing 85% styrene with approx. 15% butadiene. Since such materials cannot be transformed to elastic materials by vulcanizing they are usually referred to as synthetic resins. In test reinforced tile showed nearly four times greater resistance to 25% deformation (Instron test) than non-reinforced.

A Survey of Rubber and Resin-Rubber Soling Materials—*L. P. Smith, Ph.D.*

Results of a test involving the use of Resin-rubber, leather and a PVC compound as soling material for shoes furnished to about 100 technical school boys revealed "that a good quality resin-rubber compound has three to four times the wear life of leather and two to three times that of a PVC compound." PVC in another test wore about three times as long as leather in dry conditions and twice as long in wet.

Rubber and resin-rubber materials are recommended to the footwear manufacturer on the basis of consistency of quality and price, reduction of wastage, ease of manipulation, and in most cases a reduction in price. Since only 6% of British footwear is export and imports are increasing, the author recommends new techniques (possible with non-leather materials) be adopted.



Specifications of...

L-2A-8 oz. LESTERS

Ounces General Purpose Polystyrene	
a. Single Feed Stroke	8
*b. Double Feed Stroke	12
Mold Closing Pressure, Tons	300
Beam Area, Sq. In.	110
Pressure on Material at End of Plunger, P.S.I.	20,000
Speed of Injection Plunger, inches/min.	171
Filling Speed, cu. in./sec.	12
Complete Machine Cycle, idling, secs.	9
Mold Opens, inches	10
Maximum Mold Height, ins.	16
Minimum Mold Height, ins.	13
Maximum Mold Size, ins. (H x V)	28 x 23
Total Heating Units, K.W.	11.1
Combined Pump Capacity, gal./min.	62
Motor Size, Horsepower	30
Weight, Lbs.	19,000

*Optional at extra cost.

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SECTION NEWS

Edited by
David Mersey
190 Camden Road
Hamden, Connecticut

Pioneer Valley

Nylon 6, Lexan and Nylon 6, 6— Their Properties and Advantages

Gerald E. Berlyn

The newly elected officers of the Pioneer Valley Section for the year 1958 are: John T. Moore, President; Bruce H. Robertson, Vice President; Dominic DiPierro, Treasurer; Jack Berger, Secretary.

A program on New Materials was held at Wachusett Country Club on January 8, 1958. Mr. Richard Bishop, Director of Research in Petrochemical Division of the Foster Grant Company aptly told the story of his company's entrance into the manufacture of nylon 6 and was followed by Mr. R. J. Thompson, Sales Development Specialist, General Electric Company, who spoke on Lexan.

Mr. Bishop stated that nylon 6,6 is made from a 6 carbon base, hexamethylene diamine, and a 6 carbon acid, adipic acid. Nylon 6 is made out of caprolactam, an aminoacid of 6 carbons, hence, the difference in nomenclature. In Europe, caprolactam monomer is produced from phenol where the supply is large, however, in the U. S. a more logical source is a petroleum product, cyclohexanol. While hexamethylene diamine, and adipic acid are produced from the same raw materials, Foster Grant feels that there is a potential for lower cost raw materials in the manufacture of nylon 6. Lower processing costs and the ability to alter molecular weights of materials more easily have made the production of nylon 6 more attractive than nylon 6,6. Nylon 6 is basically a high impact material with excellent abrasive resistance, high melting points, self-lubricating properties, and excellent chemical resistance. Its electrical properties are only fair. Large parts may be more easily molded from nylon 6 because it has a wider plasticizing range yet requires lower heat than nylon 6,6 which sets up much faster. This material is suitable for injection molding, extrusion and blow molding.

Mr. Thompson stressed the four strong points of Lexan. The notched Izod impact strength is in the range of 12-16 ft. lbs. per in. of notch, heat resistance to thermal-oxidative degradation is up to 300°F, dimensional stability is excellent, and electrical properties are good. Heat distortion range is 280-290°F.

Lexan is a polycarbonate resin made by a condensation reaction. This reaction occurs by splitting out hydrochloric acid from a bifunctional phenol to give a linear polymer consisting of bisphenol groups joined together with carbonate linkages. This is only one resin of the polycarbonate family and many variations are possible.

Southern

Prize Plan Started

Sam Rutland

The first meeting of 1958 was held January 20 at the Architects and Engineers Institute Building, 230 Spring Street, N. W., Atlanta, Georgia. Presiding officer was our new president, Mr. Bill Erb.

Our program co-chairmen, Mr. Ray Kruse and Brad Nicholson, discussed their tentative program plans for the coming year and solicited opinions on several proposed projects.

At this meeting a policy of drawing for a door prize was instituted. The drawing will be made from the names of the total membership but only those present at the meeting are eligible to win, so in addition to the usual benefits, there is added inducement to attend meetings.

After dinner the members visited the Department of Industrial Design at Georgia Tech. The visit was conducted by Mr. N. Worell and Mr. H. Bredendiech, of the Georgia Tech faculty. Mr. Bredendiech explained the basic philosophy and objectives of Industrial Design and showed many interesting exhibits of students' work.

Newark

'Stump Experts' Panel Program

Robert A. White

The January meeting of the Newark Section was conducted by newly elected Section President Ernest J. Csaszar. Robert Hoehn, outgoing president, expressed his sincere appreciation for the support given him during his term. He reflected that a willing spirit and ever increasing interest in SPE ideals marked the year 1957 and featured outstanding growth of the Newark Section.

In his initial address as president, Ernest Csaszar spoke of the high standard of performance achieved by past section presidents, promising relentless endeavor to maintain these standards and to further the high ideals of S.P.E.

Newly elected officers and board members were introduced as follows: Vice President, Allen E. Serle, Secretary Treasurer, Albert Spaak; National Director, Donald W. Biklen; Directors, D. V. Blatter, Frank A. Lombard and Harrison W. Van Duyne.

The death of Dr. Thomas J. Blisard was announced with deep regret. Dr. Blisard had supervised the plastics engineering courses in the Special Courses Division at Newark College of Engineering. The section had benefitted greatly by association with Dr. Blisard. His efforts and his support of S.P.E. activities were largely responsible for the tremendous success of the S.P.E. sponsored Plastic Courses presented at N.C.E.

The program for the evening was a Stump the Experts panel, consisting of Molders, Mold Makers and Mold Designers. The panel moderator was E. J. Csaszar, Sales Engineer, Newark Die Company. The panel consisted of John A. Kavanaugh, Executive Vice-President Standard Tool Company; E. S. Bowers, Chief Tool Engineer, Cambridge-Panelyte Molded Plastics Co.; S. C. Snyder, Sales Technologist, E. I. du Pont de Nemours & Co.; Allen E. Serle, Shaw Insulator Company and Hiram McCann, Editor, Modern Plastics.

Prior to opening the meeting for audience participation, each panel member presented his view of a controversial theory on technique, designed to stimulate audience participation. The program was extremely successful, with many discussions continuing after closing of the meeting. Audience reaction was enthusiastic and almost argumentive on many issues.

Chicago

Beryllium Copper For Injection Molds

Joe Schmidt

The January meeting of the Chicago Chapter of the S.P.E. was held at the Western Society of Engineers on January 13th.

The principal speaker was Mr. John Kavanagh of the Standard Tool Company. The attendance numbered about 125. The lecture hall was filled to capacity.

Our speaker, John Kavanagh, discussed the uses and advantages of beryllium copper in injection molds. He cited various instances where beryllium copper mold components had decreased cycle time by between ten and thirty per cent. The speaker also mentioned the Shaw processing of casting. Standard Tool Company, he said, had been using it to great advantage in casting beryllium copper.

A lively discussion period closed the meeting. Mr. Kavanagh answered most of the questions submitted by the audience.

At the Board of Directors meeting, the following committee chairmen were appointed:

Charles Rank—Professional Activities; William Brown—Membership and Credentials; Joe Schmidt—Publicity; Ken Dahl—Educational; Robert Reynolds — Program; Frank Moore — House.

St. Louis

Marlex Properties

R. A. Karasek

The St. Louis Chapter of the Society of Plastics Engineers held its first meeting of the year, January 21st. The first part of the meeting covered the installation of new officers. These officers are as follows: Robert McDorman, President; Tom McNearney, Vice-President; R. A. Karasek, Secretary; Dick Baumgartner, Treasurer; and Christ Kacalieff remains National Councilman. New directors are Lyle Dean, Tom McNearney, and R. A. Karasek. The Chairman of the House Committee is Jack Lake and Tom McNearney remains Program Chairman.

The new president, Robert McDorman, gave a short talk outlining various phases of the S.P.E. group and his plans for the future.

The chief speaker of the evening was G. F. Blinzler, Sales Engineer, Phillips Chemical Company. The various physical characteristics of Marlex linear polyethylene were shown in chart form. There is no all-around linear polyethylene which is right for all applications; each one has its own distinctive features.

There was also some discussion as to the type of equipment which would produce the most satisfactory result such as preplasticizers, weigh feeding, direction of gating, etc., all of which were given consideration.

After Mr. Blinzler completed his talk, there was a very interesting question and answer session. The questions showed the great interest people in all phases of plastics have in this type material.

Southern California

Polycarbonate

John A. Stahmann

At a recent Board of Directors meeting for Southern California SPE, officers for the year 1958 were elected as follows:

President—Jack G. Fuller, Jr., Hercules Powder Company; Vice President—Dr. Robert Steinman, Garan Chemical Corp.; Secretary—Mr. John Stahmann, Gladding, McBean & Co.; Treasurer—Tom Schaub, Furane Plastics, Inc.; Program Chairman—Leo Costanza, Douglas Aircraft Co.; Membership Chairman—Charles Zimmerman, West Coast Plastics Dist., Inc.; National Director—John Delmonte, Furane Plastics, Inc.

Our new Directors for 1958-1961 are John Stahmann, Lloyd Dixon, Jr., and Zachary Harris.

High impact strength is one of the main reasons for the enthusiasm shown Lexan, reported Mr. W. S. Christopher during the Southern California Section's January Meeting. As Manager of Market Development for General Electric, Mr. Christopher was able to give the latest information on this timely subject. He addressed an appreciative audience of some hundred and fifty S.P.E. and S.P.I. members.

Lexan, a polycarbonate the first of this new family of thermoplastics, will be available shortly in pilot plant quantities. Besides the high impact strength, advantage will be taken of its good electrical properties, dimensional stability, and heat resistance. Costs are expected to go down from about $2.50 per pound as production increases.

Synthesis is similar to that of epoxy resins, combining bisphenol with carbonyl chloride. Side radicals can be nitrogen, oxygen, sulphur, and organics. The structure is not further cross-linked by radiation to a detrimental extent.

Lexan is extremely tough, displaying better impact strengths than nylon, polystyrene, acrylics, or phenolics. Notched Izod is between 12 and 16 foot pounds per inch. Tensile strengths are lower than nylon but show little elongation under stress.

Water permeability is about average for polymers. Gas permeability may be poor. It is stain resistant to many of the common household fluids such as coffee, lemon juice, and iodine. It is attacked slowly by ammonia, amines, and alkalies. It is solvated by chlorinated hydrocarbons, dioxane, and some other organics.

Injection molding methods are used in fabrication. Molds should be heated from 170°-200°F with a cylinder temperature of 525°-600°F. The nozzle should be heated. Adequate pressures are from 10,000 to 30,000 psi. Generous gates should be employed.

Ontario

Educational Courses

Harry Watson

The Ontario Section of the Society of the Plastics Engineers is taking action to establish educational courses in plastics in Canada.

The section is polling the industry to find out what type of educational courses are wanted; how many people would participate in such courses and what companies would be willing to provide lecturers.

The University of Toronto and the Ryerson Institute of Technology are both interested in the results of this poll. Both will put plastics courses on their night school extension lists providing the industry can tell them exactly what type of courses are needed, can promise that the courses will be well attended; and can guarantee that the industry will supply lecturers.

The decision to do something about the lack of educational courses in plastics in Canada was made at the January meeting of the Ontario section of the SPE. This meeting took the form of a panel discussion on education in the plastics industry.

Two of the panelists were from the plastics industry. Two were from Toronto's universities. Newly elected president Al Orr, Canadian Resins and Chemicals Limited, acted as moderator.

At the close of the panel discussions there were so many questions and opinions from the floor that the usual closing hour was ignored. It was two hours beyond the normal closing hour before Moderator Orr finally called a halt.

The general feeling was that, unlike England and the U.S.A., Canada lacks educational institutes which give comprehensive courses in plastics. The educators on the panel said they would be willing to oblige, "if only you will tell us exactly what you want."

The meeting decided that the best way to answer this was to poll the entire industry. President Orr said that the poll would take the form of questionnaire circulars.

West New England

Reinforced Plastics

C. Judd Holt

Fifty-three members and guests attended the meeting of February 12, at Betty's Towne House, Agawam, Mass.

It was "Reinforced Plastics Night." Walter E. Klesper (Holyoke Wire & Cable) was technical chairman.

William F. Condon, vice president of Cordo Molding Products, Inc., was guest speaker.

Three section members also participated in the program. They were: George W. Martin (Holyoke Plastics Corp.); Thomas A. DeMarco (Monsanto Chemical Co.); and Dr. Frederic J. Locke (Monsanto).

At a special board of directors meeting held prior to the general meeting Arthur W. Logozzo (Nutmeg Chrome Corp.) was elected the section's national director. Logozzo, a former president of the section (1955-56), will fill the post recently vacated by George Martin when he was elected national secretary at the Detroit ANTEC.

Condon described the reinforced molding compounds and preimpregnated fabrics produced by his firm and spoke generally on the present and future roles of such material in the aircraft and missile fields. He had with him a comprehensive product display to illustrate his talk.

The three local members brought the section up-to-date on the professional activities and educational programs.

Martin, who headed up the professional activities group nationally until he accepted the secretarial post, discussed what progress has been made at the national level and described the overall objectives of the program.

DeMarco, chairman of the section's professional activities committee, reported that 51 members had expressed interest in participating in the new program. He said his committee expected to activate sub-committees on extrusion, injection molding and compression molding within the next few months.

Locke, who is educational chairman for the section, described the activities of his committee and gave members a fill-in on the status of plastics education locally. He urged plastics firms to cooperate with schools offering courses which lead to careers in plastics engineering. One way local companies can help is by offering summer job opportunities to students enrolled in such courses, he said.

Cleveland-Akron

Economies of Vacuum Forming vs. Molding

Milan Krajcik

A new year started for the Cleveland-Akron Section of the Society of Plastics Engineers with the January meeting held at the Spanish Tavern in Brecksville, Ohio.

Retiring President Ed Campi, along with his officers, received a well deserved vote of thanks for his guidance to a successful year in 1957. The newly installed President, W. D. Martin, who is associated with International Molded Plastics in Cleveland, Ohio, then took the reigns for the coming year, and we can be sure that with the active support and participation of all members, we can face the challenge presented by past accomplishments and accomplish even more under the guidance of our new President.

New officers introduced by Mr. Martin are as follows:

Vice President—Wm. A. Messina; Secretary—E. J. Haskins; Treasurer—D. R. Butler; National Director—E. P. Moslo; Section Directors—Sherman Crawford, Ralph Rohlfing, James Jones, Bill Martin, Edward Haskins, Bill Messina, Harold Olson, Don Butler, Milan Krajcik.

Two speakers, R. L. Lee and H. C. MacDonald of Dow Chemical Co. were featured. The speakers were both interesting and informative.

Mr. Lee had as his subject "The Economics of Vacuum Forming vs. Injection Molding", and pointed out very aptly that extremely thin parts, such as sundae or banana split dishes, made from polystyrene can be made more economically by the vacuum forming method. It was also quite apparent, from his remarks, that injection molding is more economical for parts which must have design features other than those suggested by the above parts.

Mr. MacDonald's topic "Opportunity is Dead", on the surface, would indicate that a very gloomy future is in store for us. However, his graphs and charts, which showed a constant upward trend, belie this assumption. He pointed out that with sound merchandising methods and agressiveness, we can rest assured that "Opportunity is **not** dead". There is still more room at the top of the charts.

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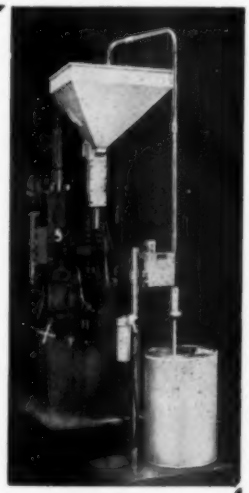

Model 512

Kansas City

Midwest Research Institute Explained

K. A. Kaufmann

The January meeting of the Kansas City Section took place on the evening of January 22, 1958 at Wolferman's Restaurant on the Country Club Plaza.

The new officers and committee chairmen assumed their offices as listed below:

President—Carl W. Bontemps; Vice President—John Comeau; Secretary—Robert Thomson; Treasurer—William Prelogar; National Council—Fred C. Sutro; Program Committee—Phillip G. Fleming; Membership Committee—Kenneth A. Kaufmann; Professional Activities Comm.—Leo B. Croley; House Committee—John Comeau.

In spite of the snow there was a fair attendance. Mr. Howard Gadberry, Head, Industrial Chemistry Section, Midwest Research Institute presented a discussion of the facilities, organization and capabilities of the Institute in various fields including plastics. This interesting talk was nicely illustrated by a number of color slides shown by Mr. Gadberry.

Mr. Gadberry noted that the organization of Midwest Research Institute is set up along disciplinary lines rather than industry lines, such as Basic Chemistry, Biological Research, Chemical Engineering, Physics, Electronics, Economic, Marketing, Operations Research, and the like, to facilitate a team approach to problems.

Specialty areas of interest have been: automation and automatic controls, low angle X-ray scatter for investigation of fatigue and stress problems, and cancer chemotherapy.

No plastics group as such exists but various teams have become proficient in resin synthesis of new and unique materials, unusual physical, basic molecular measurements, structural applications and unusual adhesives. The six major areas of plastics of interest are resin research and development; applications research; engineering handling of plastics; plant trouble shooting; sheets, the films and packaging with plastics; and biomedical problems.

Mr. Gadberry's talk was very interesting and full of details about various unusual problems which have been solved at the institute and was much enjoyed by those attending.

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(See Page 11)

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Rocky Mountain

New Officer Slate

At the January 23rd meeting of the Rocky Mountain Section of SPE, the new officers for 1958 were elected. The newly elected men are: President, Prof. Paul Barrick, University of Colorado; Vice Pres., Wayne F. Robb, Pres., Tooling Specialties, Inc.; Secretary, Prof. Dick Crawford, University of Colorado; Treasurer, Ray Millard, Pres., Denver Plastics, Inc.

At the meeting, two new members Ray L. Hauser, Martin-Denver Co., and Bill L. Williamson, Ingwersen Mfg. Co., Inc., were welcomed, making a roster of 28.

On March 20, "Optical Design with Plastics" will be the topic of Mr. James Crate of E. I. du Pont Co. Dinner and meeting at 7 and 8 are to be held at the Oxford Hotel.

As a service to the Rocky Mountain area, the Rocky Mountain SPE Section has arranged a panel to help solve any problems concerning the use and applications of plastics.

Our guest speaker for the evening was Mr. Dick Askew, Western District Manager for Phillips Chemical Company. Mr. Askew spoke and presented color slides on Linear Polyethylenes as produced by Phillips. The speech proved to be very interesting and informative.

Chairmen appointed by the president are: Professional Activities, Wayne Robb; Program, Dick Crawford; Publicity, John Lindsey; House Chairman, Bill Williamson; Nomination, Vernon Leonard; Election & Inspection, Neal Yorker; Education, Mike Hiza; Membership & Credentials, Tom Taplin; By-Laws, Jack Pechman.

Board of directors members are: Ray Millard, Dr. Ray Hauser and Harold Smith, 3 year term; Tom Taplin, Wayne Robb, and Oscar B. Yorker, 2 year term; and Egon Weiselman, J. Ellis Chaney and Paul Barrick, one year term. Oscar B. Yorker was appointed National Councilman.

Milwaukee

Officers Elected

James S. Hearons

The January meeting of the Milwaukee Section of the SPE was held Tuesday, January 21, at the Bavarian Club at 6:00 P.M. dinner included.

The meeting was opened by our new president, Tom Hardeman, and notes on future meetings were given by Herb Goeden. Meeting dates and the place of the meetings have been changed to the third Tuesday of each month at the Bavarian Club, 5423 North Port Washington Road, Milwaukee, Wisconsin.

The speaker of the evening was Harold Sexauer, sales engineer for the Elox Corporation of Michigan. Mr. Sexauer showed a film and discussed electrical discharge machinery of plastic molds. It was a most interesting presentation and the question and answer session was very lively.

The following new officers were recently elected for the coming year: Thomas R. Hardeman, President, Hardeman Laminating Incorporated; Herbert Goeden, vice president, Continental Can Company; Robert Giles, secretary, American Motors Corporation; George Gray, treasurer, Cadillac Plastic Company; T. Walter Noble, national director, Decar Plastics.

Section directors are: Charles E. Egan, Owens-Corning Fiberglas Corp., 2 years; A. J. Simmons, Plymouth Industrial Products, 1 year; Harold Hulterstrom, Flambeau Plastics, 1 year; Clarence Stowe, Stowe Plastics, 1 year.

The following are committee chairmen: Professional—Tom Hardeman, Hardeman Laminating Incorporated; Publicity & SPE Reporter—J. S. Hearons, Owens-Corning Fiberglas Corporation; Membership — Richard Allen, Celonese Corporation; House—John Verburg, Continental Can Company; Program—Joe W. Stewart, A. O. Smith Corporation; Assistant Program—Marvin C. Stowe, Stowe Plastics Products; Editorial—Harry Bertzlaff, A. O. Smith Corporation.

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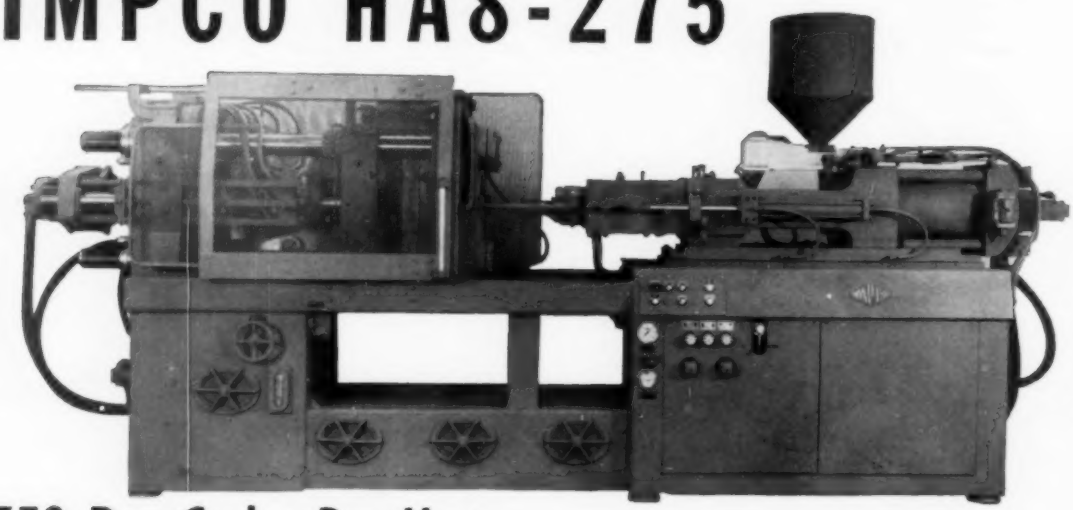

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(Please turn to page 72)

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(Continued from page 48)

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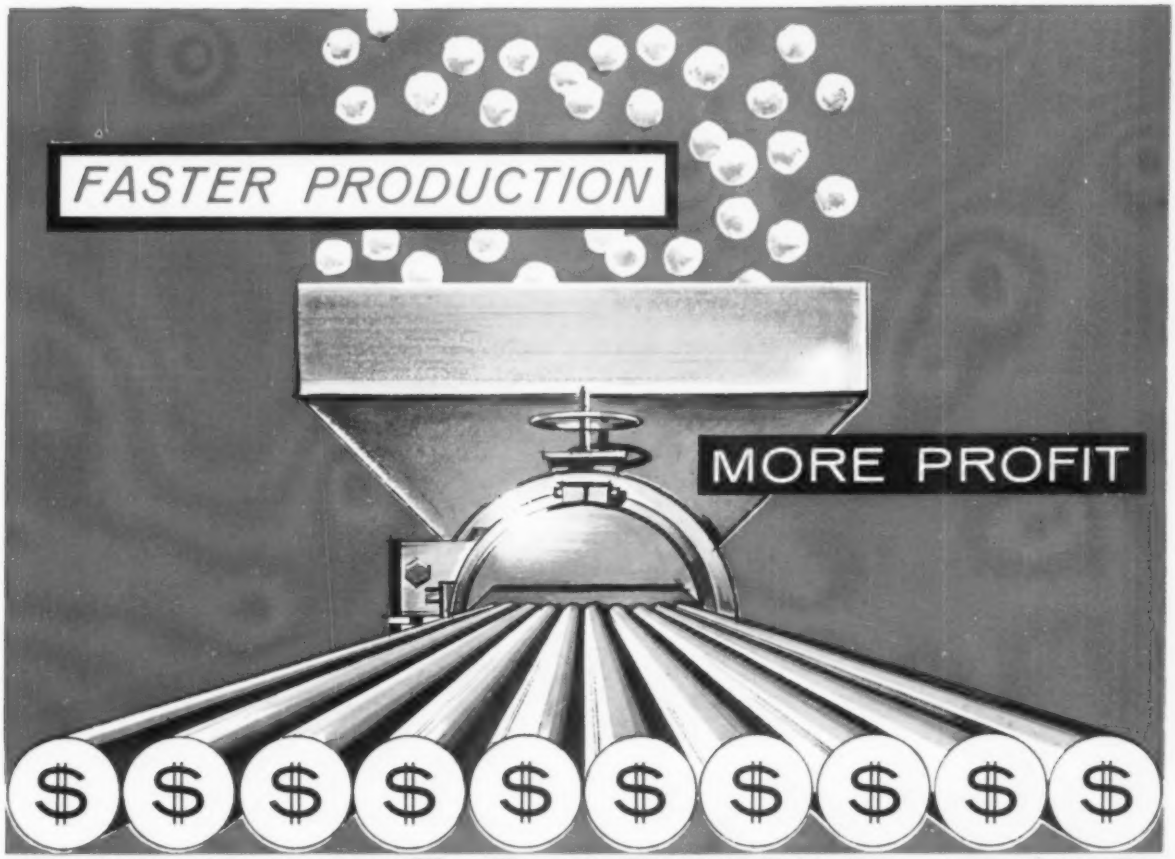

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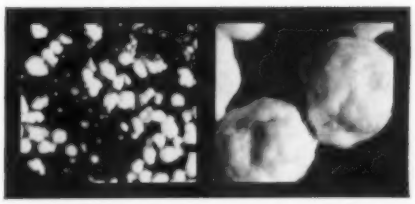

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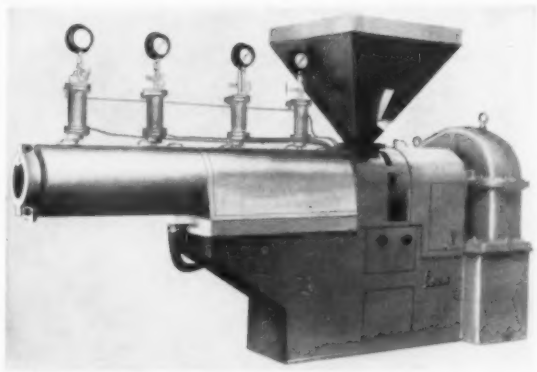
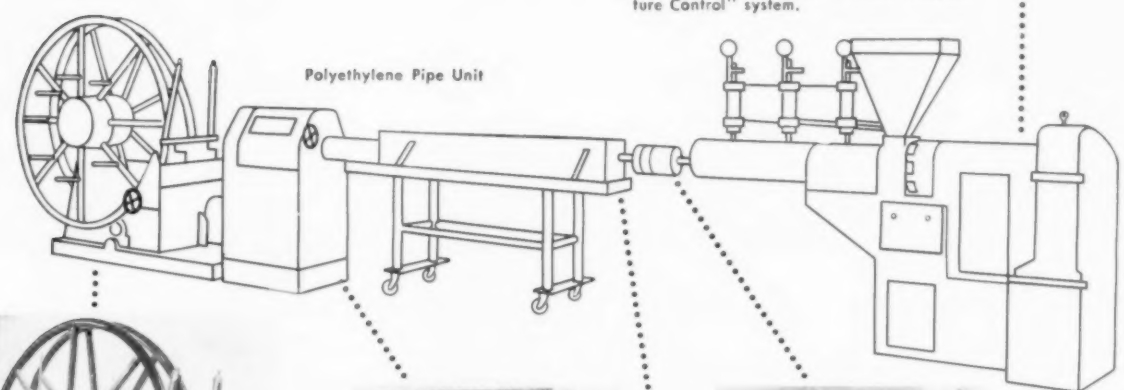
The success story behind every Egan installation is the extruder proper. Egan Extruders with patented "Willert Temperature Control" systems provide automatic, balanced temperature levels, which result in closer tolerance extrusions with greater speed and ease.

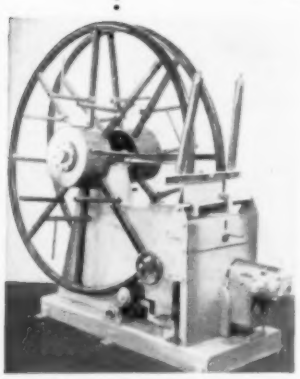
Complete extrusion installations or accessories available for pipe, film, sheet, shapes.



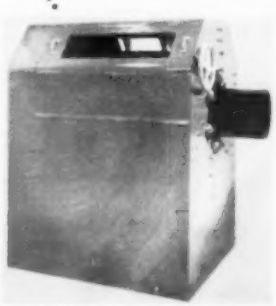
*EGAN EXTRUDERS: pre-set the temperature; "Willert Temperature Control" system takes over, providing completely automatic instrumentation.
*also available without "Willert Temperature Control" system.



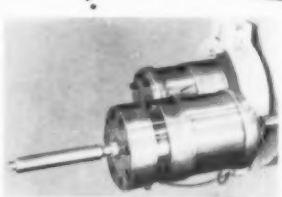
Polyethylene Pipe Unit



COILERS: dual reel type, with or without automatic level wind.



TAKE-OFFS: roller or multiple belt types in diameters of ½"—6" or 3"—14".



DIES: offset or straight-out, with or without extended mandrels.

COOLING TANKS: with vertical and horizontal adjustments.

FRANK W. *Egan* & COMPANY

SOMERVILLE, NEW JERSEY

Manufacturers of plastics processing equipment

Cable Address: EGANCO —SOMERVILLE NJER

Write, or Phone Randolph 2-0200
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